PHYSIOLOGY

BY THE LABORATORY METHOD

BRINCKLEY

WITHOUT INDEX OR GLOSSARY

THE LIBRARY OF CONGRESS
1800

Class QF 42
Book I 84
Copyright No.

COPYRIGHT DEPOSIT.

The Index and Glossary are in type, and will be corrected and completed so that the entire volume will be ready for school use by August 25, and sample will be sent on application.

The list price is $1.25. We pay the freight charges on Introduction orders, taking back in exchange new books on hand, displaced, dollar for dollar, and making a *net exchange price* of 75 cents, with a discount of 10% on Introduction for all books not exchanged.

Please address,

AINSWORTH & COMPANY,
378-388 Wabash Avenue,
Aug. 1. 1902. **CHICAGO, ILL.**

Physiology

by

THE LABORATORY METHOD

For Secondary Schools

By WILLIAM J. BRINCKLEY, Ph.D.
Vice-President and Professor of Biology in Austin College, Effingham, Ill.

Profusely Illustrated

Chicago:
AINSWORTH & COMPANY
1902

QP42
.B84

THE LIBRARY OF
CONGRESS,
Two Copies Received
AUG. 8 1902
Copyright entry
Jan. 6-1902
CLASS a XXc. No.
24398
COPY B.

Copyright, 1902
By William J. Brinckley

All rights reserved

THE LIBRARY
OF CONGRESS

PREFACE.

A PROMINENT educator has said that modern education consists of the three L's rather than of the three R's; i. e., of the laboratory, the lecture, and the library.

While this ideal cannot be realized in its fullness except in our universities and larger colleges, its basal principles are applicable to all grades of instruction. In other words, we study things and phenomena, not books.

The lecture, the library, and the text are to confirm, extend, and supplement the work of the laboratory. The text-book becomes, then, not something to be learned by rote, but something to assist the pupil in his inquiry for truth, and should contain such a statement of the subject considered as will answer all reasonable inquiries relative to an elementary notion of the subject considered. It should contain such information as will enable the student to complete and organize the facts gathered by observation in experiment, and as will awaken a desire to know more.

In our enthusiasm over method we should not forget that we study to know, as well as to have power to do, and especially is this true in the study of the human body. We have the control and guidance of the most wonderful of mechanisms, and while it is important that we use correct methods in obtaining information in regard to this mechanism, it is of vital importance that we possess sufficient knowledge of its structure and actions to secure to ourselves, under ordinary conditions, good health. Such certainly cannot be secured by a mere statement of facts of hygiene, but only by such a knowledge of the structure and principles of the body's normal action as will enable us to treat our bodies in a rational manner.

The author has given a number of subjects a fuller treatment than is commonly given to them in works of this grade, as experience has shown that pupils cannot form a

CONTENTS.

APPENDIX.

LIST OF ILLUSTRATIONS.

APPENDIX.

Physiology

By the Laboratory Method.

CHAPTER I.

EXPERIMENTS AND DEMONSTRATIONS.

Classes of Bodies.— 1. Examine carefully a pebble, a blade of grass, and a fly, or other insect, and make a list of the things in which they differ.

2. Place some sand and some wheat grains in a box where they will be free from moisture and sunlight. Put some grains of sand and some grains of wheat in soil which you have placed in a box of convenient size, and put in a warm place where they will have plenty of sunlight. Keep them well watered. Examine them every day, and note any changes that take place. How do you account for the difference in what takes place? Why do they each remain unchanged in the first case? What have you learned that is essential to the life and growth of the wheat grain? What would happen if you should place a grasshopper or a fly in a box where it could get only soil, water, air, and sunlight? Why? What do the grasshopper and the fly live on? What does this teach?

3. Plant some seeds of the bunch bean or dwarf pea, and note carefully what takes place. Are all the parts alike? Can you think why the parts are not alike? why the leaf differs from the stem, or the roots, or the flower?

4. Get some snail's eggs or frog's eggs, and put them in a vessel of water in a warm place. Carefully watch them from time to time. What do you learn from these observations?

A body which behaves like the grain of sand is called a mineral; one like the grain of wheat or the bean, a plant; and one like the fly, an animal. Make a list of the things you have observed of each.

Query 1. Upon what are plants dependent for their life and growth? the animals?

Query 2. What would happen to plants were there no soil? To animals if there were no plants? Why do we need to study animals?

5. Prepare for dissection a rat or a rabbit as directed in the Appendix. Notice the general plan. If you should divide the body into halves (right and left) on a middle (*median*) line drawn from above downward, how would the two parts compare? What name shall we give to the front surface of the body? to the rear surface? Into what parts is the front surface divided? How is the rear surface divided? Examine diagram, Fig. 1.

6. Examine transverse section of a tadpole or a salamander, prepared as directed in the Appendix. Notice (1) a large cavity, (2) a small cavity. How do they differ in their boundaries? The larger cavity is called the *ventral,* or *hœmal* (Fig. 2); the smaller, the *neural,* or *dorsal,* cavity.

7. Begin at the chin, and divide on a median line the anterior surface of the specimen of Experiment 5, carrying the line to the upper part of the pelvis. Examine the contents of the cavities thus exposed. Into how many parts is the cavity divided, and by what kind of membrane? By means of the diagram (Figs. 5 and 6) learn the names of the parts (*organs*) contained in the cavities. Notice form, size, and relation of each. Make an outline drawing of the cavities and their contents.

8. Remove the skin from the back part of the skull and the back. Saw into the skull-cavity, or remove the bone by means of the bone forceps so as to expose the contents of the cavity. Continue the line down the back, cutting away the bones with bone forceps, to near the end of the backbone (*vertebral column*). Determine the name of the organs contained in these cavities. (See Fig. 3.)

9. Remove a small portion of the skin from the leg or soles of the rabbit. (It is best, however, to shave off the hair from the part from which you take the portion of skin before removing it.) Harden the specimen by placing it in a two-per-cent solution of chromic acid for a week. Then transfer to sixty- and then eighty-per-cent alcohol. Make a vertical section, and stain in picrocarmine, mount

section in glycerin, and observe that it is made up of two portions, the outer one of which is composed of little bodies (*cells*) more or less rounded, the inner of fibrous material.

10. Take out some of the flesh (muscular tissue), and examine the little fibers first with a two-thirds and then with a one-fifth objective.

11. Examine a prepared section of the posterior ganglion of the spinal nerve of a cat; also a section of the spinal cord. Notice the numerous little bodies which make up the greater part of the substance of these bodies.

12. Examine a vertical section of the tongue of a cat. Notice the structure of the membrane (*mucous membrane*) which covers it. Observe that in Experiments 7, 8, 9, 10, and 11 we have examined organs whose essential structure is cellular. We class such organs in the *Cellular System*. See if you can determine what organs belong to this system.

13. Take the specimen used in Experiment 5. Place the animal upon its back. Notice the tube-like body (*trachea*) in front, in the neck; trace it to some of its smaller branches. Of what do the lungs seem to be chiefly composed?

Notice what kind of vessels come to it and go from it. Do you know what these tubes are called? Trace the larger ones for some distance. What do you learn?

Remove the lungs and heart. Examine the tube (*esophagus*) lying back of them. Trace it in its course through the body. Notice that while it is expanded in some parts and contracted in others it is in reality a single long tube.

14. Examine a prepared section of the skin with a one-fourth objective. Notice the little knot of tubes (*sweat glands*) originating in the lower part of the skin and passing upward and opening on its surface.

What do you think would be a good name for the system which includes organs whose essential structure is that of tubes or modified tubes? See if you can find other organs than those we have examined which belong to this system.

15. Remove the skin of the cat or rabbit you have been studying. Notice how it is attached to the body. How

is the flesh (*muscles*) bound together? What is it that gives firmness and support to the limbs? Examine the organs in the abdominal cavity, and notice how they are bound together. Why are they so carefully bound together? What seems to be the use of these structures? To this system we give the name of the *Skeletal System*. It may seem to you that we have grouped together things which are very much unlike; our later study, however, will show us they are very closely related in structure and origin.

16. Examine the teeth, tongue, and muscles of the face, jaws, and salivary glands. How do they compare in form and structure? Can you think of anything they work together to perform? Do you know what we call such a group of organs? See if you can find other groups of organs, differing in structure and form, which act together to do a common work. Such a group of organs is called an apparatus. Examine Fig. 7, and see how your observations agree with the statements made there.

THE HUMAN BODY.

INTRODUCTION.

Its Relation to Other Bodies.—We have learned that the separate portions of matter are called bodies; as a pebble, an apple, and a cat. While there are many millions of these, differing in size, form, properties, and actions, yet we may put them in one of two groups.

In the first group we class those that are of simple composition and structure; that do not increase in size except by addition of particles to their surface; that do not require food; that do not have life. Such bodies are called *minerals.*

In the second group are included those which are of a complex structure and composition; increase in size (*grow*) by taking food; have a regular cycle of existence, i. e., are brought into existence (*birth*); attain a certain size and development (*growth*); bring forth forms like themselves (*reproduction*); decline; die. These are *living bodies,* or *organized bodies.* To the first group belong the soil, rocks, the earth, air, and water; to the second, the various plants, animals, and man.

While the minerals, plants, and animals are apparently so different and unrelated, they are, in fact, very dependent,—the plant on the mineral, the animal on the plant and mineral. How are plants, animals, and minerals dependent?

The human body is the greatest and most wonderful of living forms, yet it is related in many ways to the lower forms, and the study of these aids us very much in understanding our own bodies. In fact, most of the principles of life action and function of organs have been learned by experiment on lower animals.

The animals which have been of most service to us in this way are the amœba, the frog, the cat, and the dog.

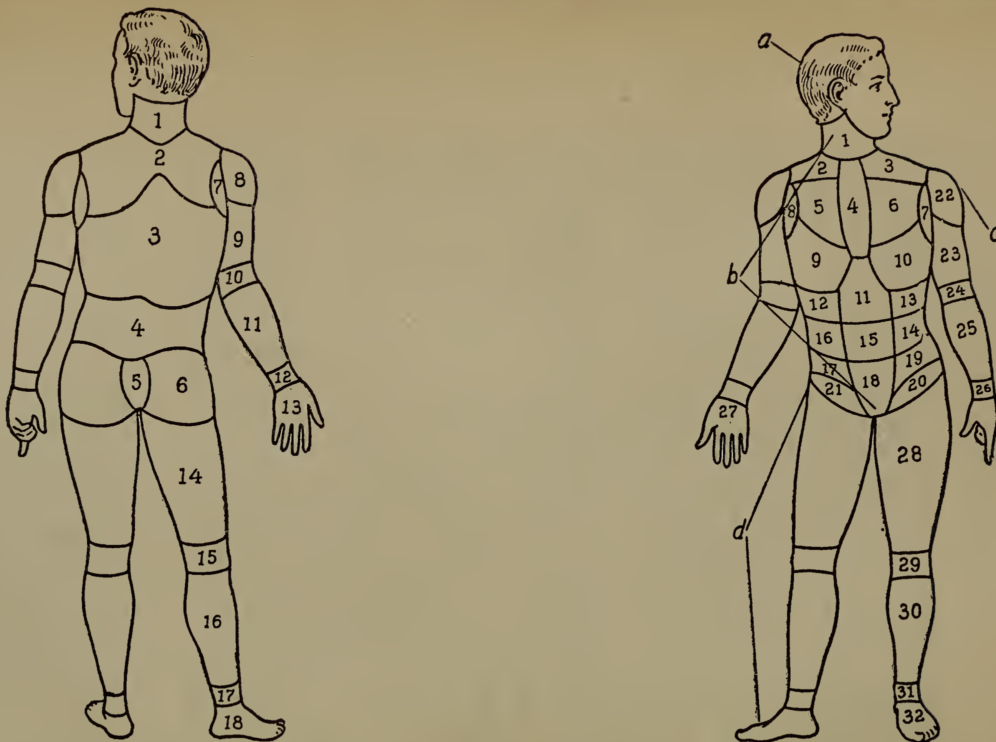


FIG. 1.— REGIONS OF THE BODY, ANTERIOR VIEW.

1. Cervical. 2. Right clavicular. 3. Left clavicular. 4. Sternal. 5. Right pectoral. 6. Left pectoral. 7. Left axillary. 8. Right axillary. 9. Right costal. 10. Left costal.

2, 3, 4, 5, 6, 7, 8, 9, and 10. Thoracic region. 11. Epigastric. 12. Right hypochondriac. 13. Left hypochondriac. 14. Left lumbar. 15. Umbilical. 16. Right lumbar. 17. Right iliac. 18. Hypogastric. 19. Left iliac. 20. Left inguinal. 21. Right inguinal. 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, and 21. Abdominal region. 22. Acromial. 23. Brachial. 24. Region of elbow. 25. Cubital. 26. Carpal. 27. Palmar. 22, 23, 24, 25, 26, and 27. Upper extremity. 28. Femoral. 29. Popliteal. 30. Tibial. 31. Tarsal. 32. Plantar. 28, 29, 30, 31, and 32. Lower extremity. *a*. Cephalic. *b*. Trunk. *c*. Upper extremity. *d*. Lower extremity.

POSTERIOR VIEW.

1. Cervical. 2. Scapular. 3. Dorsal. 4. Lumbar. 5. Sacral. 6. Gluteal. 7. Axillary. 8. Acromial. 9. Brachial. 10. Region of elbow. 11. Cubital. 12. Carpal. 13. Palmar. 14. Femoral. 15. Popliteal. 16. Tibial. 17. Tarsal. 18. Plantar.

The human body is the house in which we live — the temple of the soul. The care we give it will greatly affect our health, our happiness, and our usefulness. How important for us to know its structure and its workings, that we may so care for and use this wonderful body of ours that life may be made the most to ourselves and to others!

Regions of the Body.—That we may better understand its parts, let us first view the body as a whole. We may take for examination either a rabbit or a manikin.

The human body presents for study a front, or anterior, and a back, or posterior, surface. Its parts are the head, trunk, and extremities. Study Fig. 1. The principal regions of the anterior surface are the head, neck (*cervical*), chest (*thoracic*), and abdomen; of the posterior surface they are the head (*cephalic*), neck (*cervical*), back (*dorsal*), loins (*lumbar*), *sacral,* and *gluteal.* Study Fig. 1. The extremities include the upper and lower limbs. The regions of the upper extremity are the shoulder, arm (*brachial*), forearm (*cubital*), and hand. Those of the lower extremities are the thigh (*femoral*), leg, and foot.

The names which physicians and scientists give the regions of the body may be learned by examining Fig. 1.

In order to learn the internal structure of bodies, scientists generally make two sections: one, from above downward, called a longitudinal section; one crosswise, from before backward; a transverse section of the human body in the dorsal regions (Fig. 3); a longitudinal on the *median line* of the body; i. e., a line which would divide the body into two equal parts, a right and a left. From these sections we learn that the body consists of two tubes, one the posterior (the *dorsal,* or *neural,* Fig. 4), the other the anterior (the *ventral,* or *hæmal,* Fig. 4).

Notice that the dorsal cavity is surrounded by bone, the ventral only partly so. Can you give any reason for this difference in structure? Notice also that the dorsal is one continuous cavity; that the ventral is divided by a muscular partition (the *diaphragm*) into two portions, the

upper or *thoracic cavity,* and the lower or *abdominal cavity* (Fig. 3).

From the specimen you have for dissection, or from the manikin, determine the organs contained in these cavities. They may also be learned by a study of Figs. 3, 5. and 6. From these we learn that in the neural cavity is contained the *central nervous system;* in the upper portion, the *cranial cavity,* the *brain;* in the remainder of this cavity, formed by the *spinal canal* of the backbone, or *vertebral* column, is contained the *spinal cord* with its terminal nerves; in the ventral cavity, in the upper or thoracic portion, the *lungs, trachea, bronchial tubes, heart;* back of these, the *esophagus, great blood vessels, aorta, venæ cavæ, thoracic duct,* chain of *sympathetic ganglia;* and in the lower portion, the abdominal cavity, the *stomach, liver,* small *intestines,* large *intestines;* back of these, the *pancreas, spleen, chyle* cistern (*receptaculum chyli*), *great blood vessels, kidneys, bladder,* and chain of *sympathetic ganglia.*

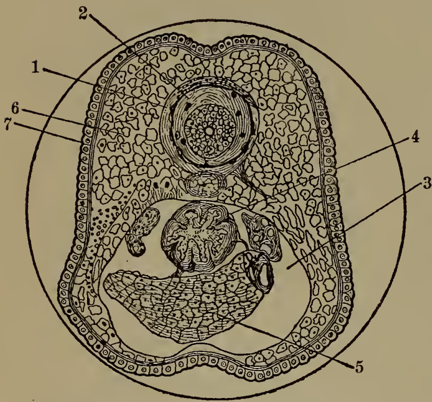


FIG. 2.—TRANSVERSE SECTION OF NECTURUS.

1. Dorsal cavity formed by the vertebræ. 2. Spinal cord. 3. Ventral cavity. 4. Alimentary canal. 5. Liver. 6. Muscles of the body wall. 7. The skin. (Brinckley, C. W. B.)

Make an outline drawing of these cavities and their contents, either from the specimen you have dissected or from the manikin, or, if you do not have these, from Figs. 5 and 6. Carefully note the relation of these parts.

Organs.—A part of a living body having a separate work to perform, the performance of which is concerned with the well-being or use of the body, is called an *organ;* as, the hand, the eye, a bone, or a muscle.

An organ may be very simple in structure, as a

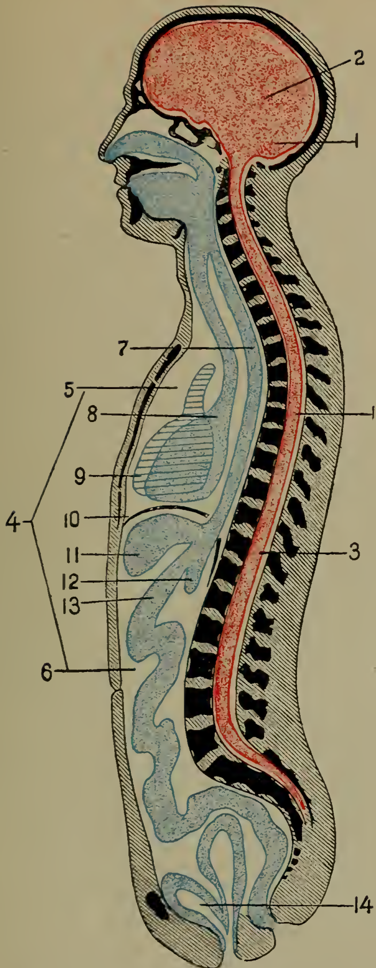


FIG. 3.—SECTION OF HUMAN BODY ON MEDIAN LINE (diagrammatic).

1. Dorsal cavity. 2. Cranial cavity, containing the brain. 3. Vertebral canal, containing spinal cord. 4. Ventral cavity. 5. Thoracic cavity. 6. Abdominal cavity. 7. Alimentary tract. 8. Respiratory tract. 9. Heart. 10. Diaphragm. 11. Liver. 12. Pancreas. 13. Stomach and intestines. 14. Urinary tract.

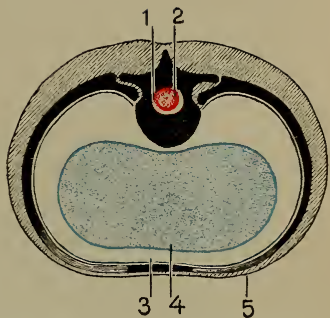


FIG. 4.—TRANSVERSE SECTION OF HUMAN BODY (very diagrammatic).

1. Dorsal cavity. 2. Spinal cord. 3. Ventral cavity. 4. Alimentary tract. 5. Body wall.

PLATE I.

muscle, or very complex, consisting of simpler organs, as the hand.

The work which an organ performs is called its *function;* e. g., the function of the eye is vision; of a muscle, contraction to produce motion.

Can the following parts properly be termed organs: the nose, the ear, the tongue, the arm, a bone, a nerve, a hair, and the skin? Give reasons for your answer.

Systems of the Body.—When organs have essentially the same structure, and work together to perform a common work or function, the group of organs is called a *system;* thus the muscles of the body form the Muscular System, those of the heart, arteries, capillaries, and veins form the circulatory system.

Let us now take a closer view of the body. If we should examine a small portion of the skin (Fig. 142), some nerve tissue (Fig. 83), and a portion of a muscle (Fig. 49) under the microscope, we should find the principal element of their structure to be a very small body having a more or less regular shape, called a *cell.* Those organs whose essential structure is the cell belong to the *Cellular System.*

This system is divided into three smaller ones: 1, The covering (*the skin*) and the lining (*mucous membrane*) of the body, forming the *Muco-Dermal System;* 2, the flesh of the body (*muscles*), whose chief function is to produce motion, forms the *Muscular System;* 3, the brain and spinal cord, with the nerves that go from them, with the sympathetic nerves, ganglia, and plexus, which make up the *Nervous System* (Fig. 7).

Throughout the body are numerous organs whose essential structure is that of single tubes, or sacs, or of a series of tubes; as the arteries and veins, the windpipe (*trachea*). Such structures belong to the *Tubular System* (Fig. 7).

Beginning at the mouth, we notice that it leads into an expansion (the *pharynx*), which in turn leads into a muscular tube (the *esophagus*) (Fig. 110), which expands (the

stomach), then contracts (the *intestines*), and then becomes enlarged again (the *larger intestines*). As this is the tube along which food is digested, it is called the *Alimentary System* (*alimentary canal*). Before reaching the muscular tube we find an opening (the *glottis*) leading into a funnel-shaped box (the *larynx*), surmounting a tube (the *trachea*), which becomes very much branched (the *bronchi*), so as to make a complicated system of tubes, forming the greater part of the lungs. As this is the tube by which we breathe, it is called the *Respiratory System*. Could we trace one of the little blood vessels in its course, it would be seen to join with others, and these with still larger ones, until they form a great trunk extending to the heart, and here would be found various large tubes going to and from the heart. These, with the heart and the tubes which carry the lymph, since they are the means by which the materials are carried to and from different parts of the body, are called the *Circulatory System*.

In various parts of the body are found bundles, or a network of tubes, whose purpose is to form materials, fluids, and solids for the use of the body; these form the *Secretory System*. For the organs which belong to this group, see Fig. 7.

There are also collections of tubes, in some cases very complicated, whose purpose is to remove waste materials from the body; these form the *Excretory System*.

The Tubular System, therefore, may be divided into: 1, The one for the digestion of food — the Alimentary System; 2, the one by which we breathe — the Respiratory System; 3, the one by which material is carried to and from various parts of the body — the Circulatory System; 4, those making material for use of the body — the Secretory System; 5, those for the removal of waste products — the Excretory System.

For the relation of the systems to the organs which they contain, see Figs. 5 and 6.

As we have seen, the muscles, nerves, and delicate organs

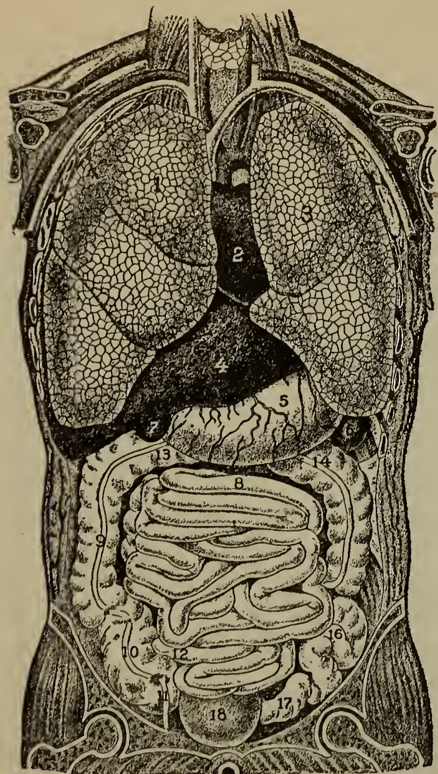


Fig. 5.—Superficial Viscera. (From Yaggy's Anatomical Study.)

1. Right lung. 2. Heart. 3. Left lung. 4. Liver. 5. Stomach. 6. Spleen. 7. Bile cyst. 8. Small intestines. 9, 10, 13, 14, 16, 17. Large intestines. 12. Ileum, ending of small intestines. 10. Cæcum, beginning of large intestines. 11. Vermiform appendix. 9. Ascending colon. 13. Transverse colon. 14. Descending colon. 16. Sigmoid flexure of colon. 17. Rectum. 18. Bladder.

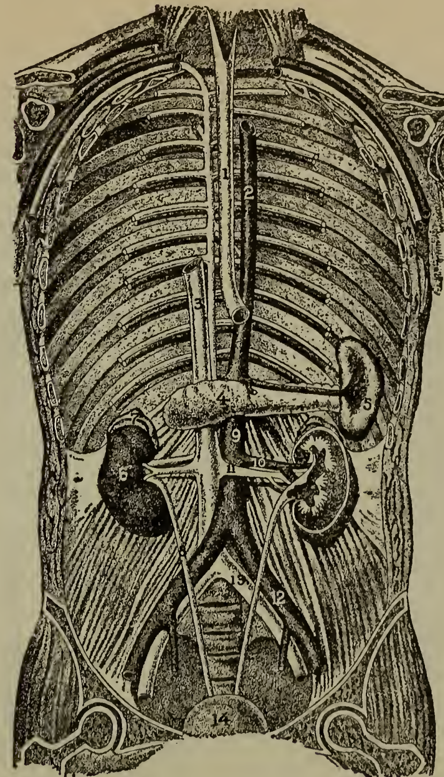


Fig. 6.—Part of Deep Viscera. (From Yaggy's Anatomical Study.)

1. Esophagus. 2. Thoracic aorta. 3. Ascending vena cava. 4. Pancreas. 5. Spleen. 6. Kidney. 7. Suprarenal capsule. 8. Ureter. 14. Bladder. 13. Left common iliac vein. 12. Left common iliac artery. 10. Renal artery (left). 11. Renal vein (left). 9. Abdominal aorta.

need protection and support, and without such support our bodies would be like that of the jellyfish, and as helpless as it would be out of the water.

Again, long tubes like the intestines, if put into the abdominal cavity without support, would be in constant danger of entanglement; we therefore find them securely bound together by a delicate membrane (the *mesentery*). There are other organs which must be bound to their places. The contraction of a muscle would amount to but little, and movement of the body would be almost impossible, if the muscles did not have some firm structure upon which to act, as the bones. This investing, supporting, protecting system forms the *Skeletal System*. To this system belong connective tissue proper, ligaments, tendons, cartilage, and the bones.

Apparatus.— Organs which are very unlike in structure, which work together to produce a common work (as the muscles, bones, and nerves, to produce motion; the teeth, tongue, salivary glands, liver, and alimentary canal, to effect the preparation of the food for absorption), form an *apparatus*.

The more important kinds of apparatus of the body are those of vision, hearing, taste, smell, motion, respiration, digestion, and circulation. We shall learn later in our study the organs of which these apparatus are composed.

Fig. 7.— Diagram of the Systems of the Human Body.

- **Systems.**— Groups of organs essentially alike in structure.
  - *Cellular.*—The cell the essential element of structure.
    - Muco-dermal.
      - Skin and appendages.
      - Mucous membrane.
    - Muscular.
      - Muscles.
    - Nervous.
      - Brain.
      - Spinal cord.
      - Cranial and spinal nerves.
      - Sympathetic nerves.
      - Ganglia and plexus.
  - *Tubular.*— Tissues arranged in the form of tubes or sacs.
    - Digestive.
      - Mouth.
      - Pharynx.
      - Esophagus.
      - Stomach.
      - Intestines.
    - Respiratory.
      - Nasal passages.
      - Pharynx.
      - Larynx.
      - Trachea.
      - Bronchi.
      - Lungs.
    - Circulatory.
      - Heart.
      - Arteries.
      - Capillaries.
      - Veins.
      - Lymphatic capillaries.
      - Lymphatic veins.
      - Lacteals.
      - Thoracic duct.
      - Lymphatic glands.
    - Secretory.
      - Salivary glands.
      - Gastric glands.
      - Intestinal glands.
      - Liver.
      - Pancreas.
      - Lachrymal glands.
      - Sebaceous glands.
    - Excretory.
      - Kidneys.
      - Lungs
      - Sweat glands.
  - *Skeletal.*— More or less of tissues giving protection, form, and support to organs.
    - Connective tissue.
    - Tendons.
    - Ligaments.
    - Cartilage.
    - Bone.

CHAPTER II.

EXPERIMENTS.

MICROSCOPIC STRUCTURE OF THE BODY.

1. Prepare a specimen of the skin as directed in Experiment 9. Use a one-fifth objective for examination of the object. What do you find to be the structure of the outer layers? Make a drawing of the cell layers, carefully noting their structure.

2. Make a vertical section of the tongue, and harden and prepare as directed for the skin as given in experiment. Carefully note the covering structure, and compare with the section of the skin. Examine in a similar way the mucous membrane of the throat.

3. Take a piece of the membrane which holds the intestines together (the mesentery), and immerse in a quarter- or a half-per-cent solution of silver nitrate for a few minutes, then wash in water. Expose the membrane to the sunlight until it becomes brown; now spread it out upon a glass slide, and place it for a short time in a very dilute solution of ammonia carmine, adding a few drops of acetic acid; wash in slightly acidulated water. Add a drop of glycerin to the slide, and put on a cover glass. Examine with the microscope, and make drawing of whatever you see. In what respect do the tissues you have examined seem to be alike?

These tissues are called *epithelial tissues*. Examine the interior of various organs to see if they are lined with epithelium. Make a list of the organs in which you find epithelial tissue; also notice how the form and arrangement of the cells differ in the different organs and tissues.

4. Obtain from the butcher a portion of the large tendon or ligament (*ligamentum nuchæ*) which holds the head of the ox erect. Note the structure of the ligament. (1) Tease out in water a small portion; i. e., carefully tear it into small threads by moving the teasers the long way of the tendon.

Of what kind of fibers is it composed? Are they elastic? How do you know? Make a drawing of your specimen. (2) Add to the specimen a three-per-cent solution of acetic acid. What change takes place?

5. Get a mouse, and kill it with chloroform as directed in the Appendix. (1) By means of the forceps pull off a portion of its tail, and, keeping in position one end with a needle, separate as completely as you can the fibers. During the process of teasing, the fibers should be kept moist with a normal salt solution. See Appendix. Add a drop of normal salt solution, and put on a cover glass. Examine with the microscope. Observe the bundles of *fibrillæ*. Make a drawing. (2) Now add a three-per-cent solution of acetic acid. What change takes place? The fibers which now remain are elastic fibers.

6. (1) Make a very thin section of the head of the humerus or femur of a young animal. Mount in a normal salt solution (six-tenths-per-cent of common salt), and examine with a high power. Note, (*a*) the apparently structureless part (*the matrix*) in which are distributed, at somewhat irregular intervals, cells (*cartilage cells* or *corpuscles*); (*b*) the shape of each corpuscle, with its prominent center (*nucleus*); (*c*) that most of the cells fill up the cavities in which they lie; (*d*) the nature of the matrix, and its proportion to the number of cells. (2) Wash the piece with a one-per-cent solution of acetic acid. Note the changes which take place as washing proceeds: (*a*) changes in the nucleus; (*b*) changes in the cell's substance; (*c*) the space formed by the shrinking of the cell. (3) Place a small piece in a five-per-cent solution of gold chloride for about a half hour, or until it is of a light yellow color, then wash well with water, and place in a vessel containing water slightly acidulated with acetic acid; leave it exposed to the light.

When it has become of a red purple color (which will require in most cases one or two days), mount in glycerin. Note the changes. Make a drawing.

7. Take a thin portion of a tadpole's tail, and harden by placing in a two-per-cent solution of chromic acid. When sufficiently hardened, gently break up a piece of glycerin. Notice the hexagonal cells composing the outer layer (epidermis) of the skin. When these have been broken

away from the layer, in which are imbedded many blood vessels, a number of stellate cells may be seen. Note the layer of dark stellate cells (connective tissue corpuscles). Notice carefully their structure and relation.

8. Cut out a small piece of the mesentery from a part containing little fat. Spread it out on a slide, and mount it in a normal salt solution. Examine: (1) Put under a low power, and notice the groups of highly refractory cells. (2) Place under high power, and notice relative size and structure of the fat-cells. In what do they seem to be imbedded? Have the cells a nucleus? (3) A specimen that has its blood vessels injected. Note carefully the arrangement of the blood vessels. In what tissues and organs do you find fat? See if you can determine how fat tissues are formed. Does it seem to have any relation to connective tissues? See if you can discover the use of fat. Write a description of the tissue observed. Make a classification of tissues observed, as to essential structure.

THE MICROSCOPIC STRUCTURE OF THE BODY.— TEXT.

If we should carefully dissect any of the organs of the body, as for instance a muscle, we should find that it is made up of a number of simpler parts or membranes. These simpler structures which go to make up the organ are called *tissues*.

By dissecting out the various organs of the body, and comparing their structure by means of the microscope, we can learn more fully of their structure and the relation of the tissues. The study of the microscopic structure of organs and tissue has become a great science, and is called *histology;* and when we speak of the histology of a tissue we have reference to its microscopic structure and appearance. This science has revealed to us many wonderful truths, and made possible many things which could not have been known without it.

From a histological examination we are able to classify the tissues into the following groups: —

I. Those whose essential structure is one or more layers of cells resting upon a delicate, almost structureless layer — Epithelial tissue (Fig. 8).

II. Those whose property is to contract and relax — Muscular tissue, or contractile tissue (Fig. 14).

III. Those which can receive impressions, and send stimuli — Sensory or nervous tissue (Fig. 85).

IV. Those made up of fibers and cells, and whose chief function is to support or bind parts together — Connective tissue (Figs. 20, 21, 22, 23).

V. Those composed of liquid, in which float small bodies (*corpuscles*), and whose function is to carry material to and from the various parts of the body — Nutritive tissue, the Blood, and the Lymph (Fig. 137).

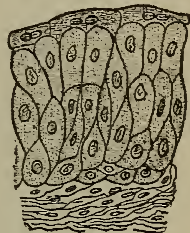


FIG. 8.— EPITHELIAL TISSUE.
Epithelium of the bladder showing the nature of transitional epithelium. Notice difference in shape of the cells.

1. Epithelial Tissue.—*Distribution.*— Epithelial tissue forms (1) the outer layer of the skin, where it is known as the *epidermis;* (2) the covering of the mucous membrane, i. e., those membranes which line the passages and cavities of the body which communicate with the exterior, as the air passages, the lungs, alimentary canal, and also ducts and tubes opening into these cavities; (3) the terminal parts of the organs of special sense, as the rods and cones of the retina, and the auditory hairs; (4) inner surface of serous membranes; i. e., the membranes lining closed sacs, as in the thorax (*pleura*), abdomen (*peritoneum*), and of the heart (*pericardium*); (5) inner surface of the heart, blood vessels, and lymphatics; (6) inner lining of the ventricles of the brain and the central canal of the spinal cord.

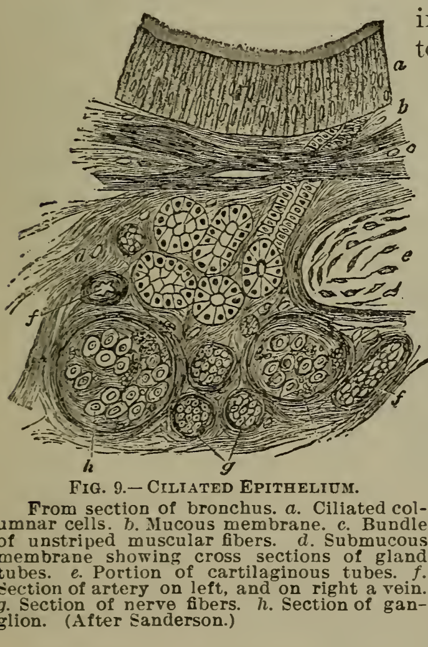


FIG. 9.— CILIATED EPITHELIUM.
From section of bronchus. *a.* Ciliated columnar cells. *b.* Mucous membrane. *c.* Bundle of unstriped muscular fibers. *d.* Submucous membrane showing cross sections of gland tubes. *e.* Portion of cartilaginous tubes. *f.* Section of artery on left, and on right a vein. *g.* Section of nerve fibers. *h.* Section of ganglion. (After Sanderson.)

Structure.— Epithelial tissue consists of cells placed side by side, held together by a small amount of cementing

substance. Epithelial cells consist of protoplasm and a nucleus; they multiply by indirect division (*karyokinesis*). As they vary in their functions,— as protecting, secreting, and receiving sense impressions,— they present a corresponding variety in form, structure, and size. As to their arrangement, they may be stratified, forming several layers, as in Fig. 9, or simply composed of a single layer. In form they may be squamous or flat (Fig. 8), columnar or cylindrical (Fig. 10), or cubical. No blood vessels pass into epithelial tissue; they are nourished by imbibition of the plasma from the tissues near them. In many parts, however, nerve fibrils exist among the epithelial cells.

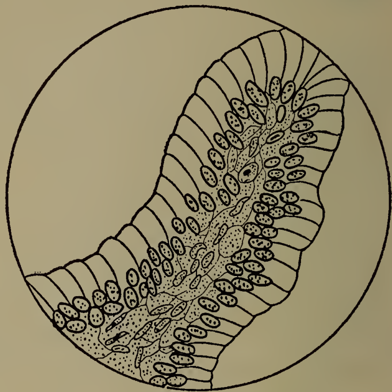


Fig. 10.—Columnar Epithelium.
Mucous membrane of villus of intestine of Necturus. (Brinckley, C. W. B.)

The more important varieties of epithelial tissues are:—

1. Stratified Epithelium.— This form of epithelium forms the external surface of the body, or the epidermis; it also lines the cavity of the mouth, pharynx, esophagus, and the anterior surface of the cornea.

Fig. 11.—Pavement Epithelium from the Mouth of a Child. (Sanderson.)

2. Transitional Epithelium.— This variety is quite widely distributed. A squamous variety lines the bladder and ureters. It consists of three or four layers of cells having prominent nuclei. The most superficial layer consists of somewhat flattened cells, each of which overlies two or three pear-shaped cells of the second layer; a third layer fills up the spaces in the second, as shown in Fig. 8. A columnar variety, consisting of three or four layers of cells, forms the lining of the larynx, trachea, and large bronchi.

3. Simple Squamous or Pavement Epithelium.— This is

made up of a single layer of flattened, many-sided cells, fitting edge to edge, as in Fig. 11. It lines the air cells of the lungs, part of the looped tubules of the kidneys, the inner surface of the iris and choroid, and the free surface of serous membranes, as the pleura, peritoneum, pericardium, and the arachnoid membrane, and the interior of the heart, blood vessels, and lymphatics.

4. Simple Columnar Epithelium. — Columnar epithelium consists of prismatic or cylindrical cells set upright, and generally of but one layer. The cells are often very irregular, due to mutual compression and the presence of lymphoid or wander cells. In many parts of the mucous membrane the columnar cells undergo modification of shape due to their distention to form the secretion of mucin, the chief constituent of mucus; becoming flask-shaped, they are called goblet cells (Fig. 26). They finally rupture their contents, forming mucus.

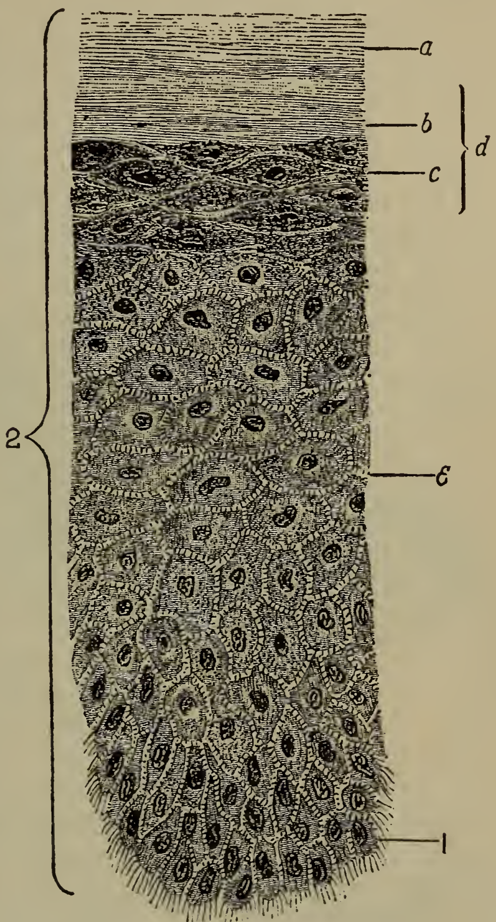


FIG. 12.—PRICKLE CELLS. (From human skin.)

1. Prickle Cells. 2. Epidermis. *a.* Layer of horny cells. *b.* Stratum lucidum. *c.* Granular layer. *d.* Stratum intermedium. *e.* Rete mucosum.

5. Ciliated Epithelium.— The cells of this tissue are usually columnar, having at their free ends hair-like processes called cilia (Fig. 9). During life, and in many cases for a short time after removal from the body, they exhibit a rapid, whip-like movement, the surface moving to and fro like a field of grain swayed by the wind. The cilia bend swiftly in one direction, and then return to an upright position more slowly, thus setting in motion in a definite direction the fluid which bathes them. It is in this way the mucus is moved along the bronchial tubes and trachea to the pharynx. Ciliated cells line the nose, the upper half of the pharynx, the Eustachian tubes, the lower part of the larynx except over the vocal cords, the trachea and bronchial tubes, the ventricles of the brain, and the central canal of the spinal cord.

6. Sensory Epithelium.— This is a curious modification of cells, found in connection with the termination of certain sensory nerves to form receptive end-organs for different kinds of vibrations, as the rods and cones of the retina (Fig. 159), and the auditory hair-cells (Fig. 170). We shall study these more at length when we consider the different senses.

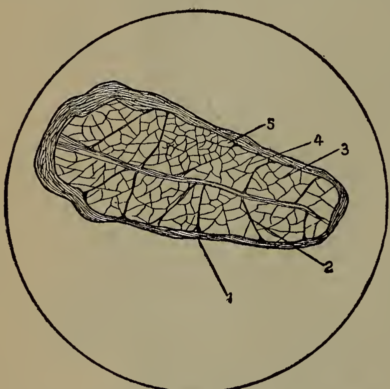


FIG. 13.—CROSS SECTION OF A SKELETAL MUSCLE.

(Section of one of the flexors of the foot of ox.) 1. Epimysium. 2. Perimysium. 3. Bundle. 4. Endomysium. 5. Fasciculus of fibers. (Brinckley, S. D. C.)

Function of Epithelium.—With the exception of the sensory epithelium, the epithelium is either protective or secretive in its functions. The epithelium forming the epidermis, the lining of the air passages, and the eyelids, is mainly protective, while that of the salivary glands, the gastric and intestinal glands, of the liver, of the pancreas, and of the sweat glands is secretive.

Ciliated epithelium, in addition to being protective, aids by its movements in propelling fluids and small particles from the body.

Beneath the epithelium of many tissues is found a homogeneous membrane, the *basement membrane*. That of most mucous membranes and secreting glands, however, consists of a very thin layer of flattened cells, a variety of connective tissue.

II. Contractile or Muscular Tissue.—This is the tissue that makes up what is called the flesh. It is also found as

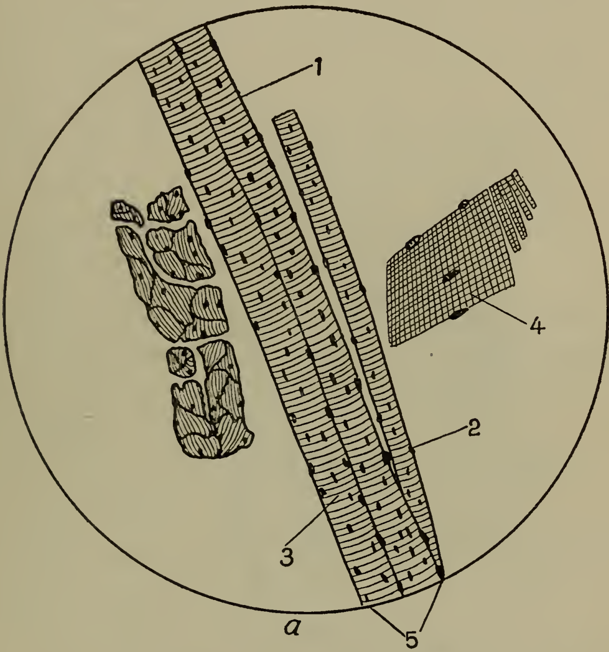


FIG. 14.

1. Striated fiber. 2. Nucleus. 3. Striæ. 4. A fibrilla. 5. Muscle fibers from tongue of cow. (Brinckley, C. W. B.)

one of the coats of the alimentary canal, in the middle coat of the arteries and veins, makes up the greater part of the heart, and is found in some other parts of the body.

The muscles attached to the bones, and concerned with the movements of the skeleton, are called skeletal muscles. Those of the blood vessels and alimentary canal are called involuntary muscles.

Skeletal Muscles.—To the eye the skeletal muscles have the appearance of being made up of numerous bundles (Fig. 13) of very small bundles, all bound together by connective tissue. The investing sheath of the muscle is called the *epimysium;* that which divides the muscle into bundles, the *perimysium.* The smallest bundles, microscopic in size, are called fasciculi; each fasciculus is seen to be made up of very fine threads or fibers (Fig. 13). While they appear to be a continuous thread, they are made up of small elongated cells placed end to end, being $\frac{1}{500}$ of an inch thick and many times longer. The fibers are usually over an inch long, and are covered with a sheath called the *sarcolemma.* They appear to have fine cross-markings, or striæ, and numerous nuclei lying close to the sarcolemma.

When specially treated, or after death of the muscle, the fiber presents fine longitudinal markings called fibrillæ. Under very high powers the muscle appears much more complex than given above, but it would take us too far to consider it here.

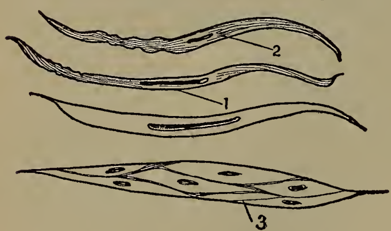


FIG. 15.—UNSTRIPED MUSCLE CELLS. 1. Nucleus. 2. Longitudinal striæ. 3 Arrangement of cells.

Besides binding and connecting the various parts of the muscle, the connective tissue (areolar) serves to conduct and support the blood vessels and nerves in their ramifications in the muscles.

Unstriped Muscle.—When we examine the muscles which go to make the muscular coats of the alimentary canal and blood vessels, we find them quite different in structure. These muscles are made up of bundles bound together by connective tissue.

The fibers are composed of spindle-shaped cells, somewhat flattened, having a length of $\frac{1}{500}$ inch and a breadth of one eighth of the length, or about $\frac{1}{4000}$ of an inch.

They have a prominent oval-shaped nucleus with well-marked network and one or more nucleoli. The cell sub-

stance presents a longitudinal striation, but no transverse marking. Each cell seems to have a delicate sheath; the cells are held together in the fibers by a small amount of cement substance.

As in the skeletal muscle the blood vessels and nerves find their way to the fibers by means of the connective tissue. This variety of muscular tissue is called plain or unstriped muscular tissue (Fig. 15). Unstriped muscle is found in the muscular coat of the alimentary canal below the middle of the esophagus, in the trachea and bronchi, in the middle coat of the arteries, in the veins and larger lymphatics, in the bladder and ureters, and in the ducts of glands.

Heart Muscle.—The heart muscle fibers resemble those of the skeletal muscle in having transverse striæ, but they differ in many other respects. The fibers often give off branches, as shown in Fig. 16. The cells are more nearly square, have a prominent nucleus placed near the center of the cell, and are without a sarcolemma. The different muscular tissues differ also in function as well as in structure. The striped varieties, except heart muscles, are under the control of the will, and are called voluntary muscles. The unstriped and heart muscles act independently of the will, and are called involuntary muscles.

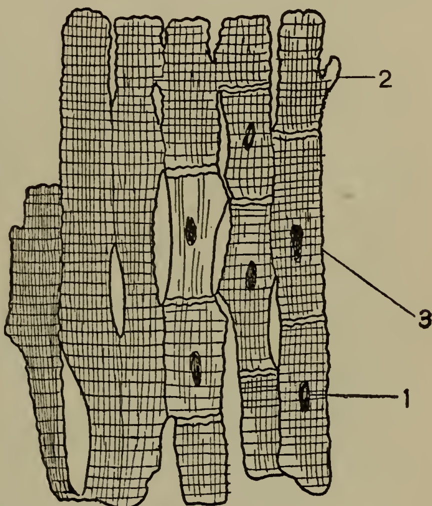


FIG. 16.—HEART MUSCLE.
1. Nucleus. 2. Branch from cell. 3. Anastomosing cells.

In action the striped, or voluntary, muscle is the most rapid, the heart muscle the next, and the unstriped muscle the slowest.

III. Nervous Tissue.— This is the tissue which makes up the brain, spinal cord, and nerves. The principal varieties are the gray nerve substance, composed of cells, and the white nerve substance, whose chief element is fibers. We shall learn more about these when we study the nervous system.

IV. Connective Tissue.—*Definition.*—The term "connective tissue" includes a number of tissues, which, while they appear to differ widely, are grouped together, owing to their common function and origin, and to their histological and chemical similarities.

Origin and Structure.— They have a common origin, being all derived from the mesoblast. Histologically they are related, in that they have, in common, three microscopic elements: a ground substance or matrix, cells, and fibers, the proportion of which varies in the different forms of connective tissue.

All varieties of this tissue, which contain white fibers, yield gelatin on boiling.

In some cases these tissues may replace each other or merge into one another, as cartilage into bone or areolar tissue into adipose. There are three principal varieties of connective tissue, viz.: —

A. Connective Tissue proper, of which there are six varieties: —

1. Areolar Tissue.—This tissue has more or less open texture, and appears to the naked eye to consist of fine, transparent threads and films crossing in various directions, and leaving, especially when stretched, open spaces, or *areolæ,* between them.

Under the microscope the transparent threads are seen to be made up of wavy bundles of very fine parallel fibers (white fibers), going in various directions, with a single branching fiber of another kind (elastic fibers).

In addition to these fibers, various forms of connective tissue cells may be found: (1) flattened connective tissue

corpuscles, (2) plasma cells, (3) granular cells. Besides these fixed forms, are cells (wandering cells) like those of the white corpuscles of the blood and lymph. Cementing the white fibers together, and forming the matrix, or basis, of the tissue, is a clear homogeneous material containing mucin, called the ground substance.

Distribution.—Areolar tissue is the most widely distributed of the connective tissues. It is found beneath the skin and mucous membrane, forms sheaths and partitions, tissues of muscles and of various organs, and binds various parts and organs together. It forms a continuous network throughout the body, investing, supporting, and binding its various parts together.

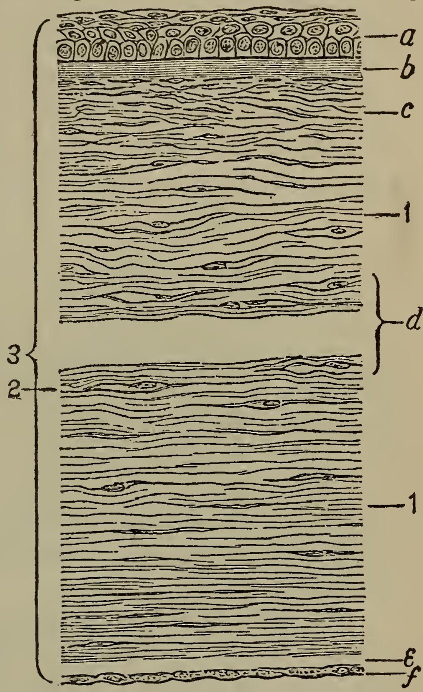


FIG. 17.—WHITE FIBROUS TISSUE (CORNEA). 1. White fibers. 2. Fusiform cells. 3. Structure of cornea. *a.* Epithelial layer. *b.* Outer elastic layer. *c.* White fibrous layer. *d.* Substantia propia (proper substance of the cornea). *e.* Posterior elastic layer. *f.* Inner epithelial (endothelial) layer.

2. White Fibrous Tissue. — *Structure.*— This tissue consists essentially of bundles of white fibers, the other elements, a few cells and cementing substances, being comparatively unimportant. The compact varieties have a shining pearly appearance, are very strong and pliant, but quite inelastic.

Under the microscope what appears to be fibers is made up of many very fine transparent fibers from $\frac{1}{50000}$ to $\frac{1}{25000}$ of an inch thick. These fibers do not occur singly, but are cemented into a bundle by a small quantity of the mucin

ground substance. While the fibers are transparent by transmitted light, in mass they appear white. The fibers run principally in one direction, and do not interlace or branch (Fig. 17).

Distribution.— This tissue forms the chief part of tendons and ligaments, is found in the true skin and the denser fasciæ, binding down the muscles.

3. Yellow Elastic Tissue. — *Structure.*— In this tissue the elastic fibers predominate. The yellow fibers are distinguished from the white by their sharper outline, yellow color, and their branching or anastomosing, and forming a network. They curl up when broken or cut across (Fig. 18). The fibers vary in size from $\frac{1}{80000}$ to $\frac{1}{24000}$ of an inch, the larger fibers being found in the *ligamentum subflava* and the finer ones in the vocal cords. They yield, on boiling, a substance called elastin, while the white fibers yield gelatin.

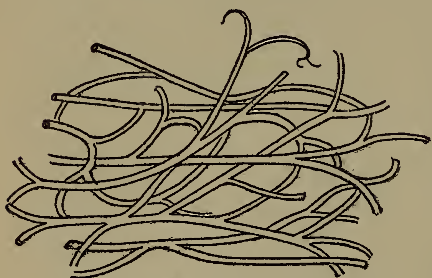


FIG. 18.—YELLOW ELASTIC TISSUE.
From teased specimen. (Brinckley.)

Distribution.— It is found in the ligament between the arches of the vertebræ, the walls of the trachea and its branches, with other textures in the coats of the arteries, and as the principal part of ligaments, in the areolar tissue, in the true skin, and mucous membrane.

4. Retiform or Adenoid Tissue.— *Structure.* — It consists of a very fine network of fibers continuous with the white fibers of ordinary connective tissue, having few or no elastic fibers. Around the fibers of the network are the cells which give the tissue the appearance of being a form of stellated cells with their anastomosing branches when the cells are not cleared away. The meshes of the network are occupied with lymph and by numerous corpuscles (lymphoid cells) resembling lymph corpuscles.

Distribution.— This is a variety of areolar tissue. It is found in the spleen, lymphatic glands, the tonsils, and in many mucous membranes.

5. Adipose Tissue, or Fat.— *Origin and Structure.*— This is developed from areolar tissue, the protoplasm of the cells having for the most part been replaced by oil, the cell wall serving as a capsule, and the fibrous element almost disappearing. Under the microscope fat is found to consist of cells or vesicles collected into lobules, these lobules being collected into clusters, which to the naked eye have the appearance of granules; the cells and lobules are supported by a small amount of areolar tissue in which the blood vessels ramify. Each lobule has an afferent artery, capillaries, and an efferent vein, but no nerves. The cells are round or oval, and vary in size from $\frac{1}{800}$ to $\frac{1}{600}$ of an inch.

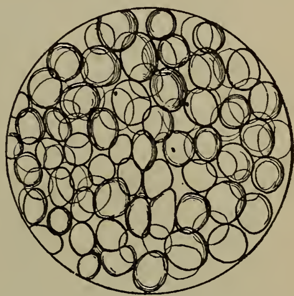


FIG. 19.—ADIPOSE TISSUE. Fat cells from the tongue of a cow. Notice that the nucleus is crowded to one side by the formation of fat within the cell wall. (Brinckley, C. W. B.)

Nature of Fat.— Fats consist of stearin, olein, and palmitin. During life the fat is fluid, but becomes solid after death. Fat often forms into needle-shaped crystals.

Use.—This tissue serves as a protective packing material, preventing the heat of the body from passing away too rapidly, as it is a poor conductor of heat; it also holds in store materials rich in carbon and hydrogen for use in the body. During starvation the fat may be absorbed and used up in the body, serving as a food, and the cells become ordinary connective tissue cells.

Distribution.—While this tissue is distributed quite generally throughout the body, it is more abundant beneath the skin, around the kidneys, upon the furrow, on the surface of the heart, and it is abundant in the marrow, but is absent from the lungs and brain.

6. Mucous or Jelly-like Connective Tissue.— This is found in the vitreous humor of the eye, and in the body during early development.

B. Cartilage.— *Nature and Structure.*— This is a tough, dense tissue, very elastic, yielding to pressure or torsion, but returning to its shape when pressure is removed.

In color it is bluish white, opaque in mass, but translucent in thin slices. On prolonged boiling it yields an albuminoid substance called chondrin, which, on cooling, hardens like jelly.

No nerves have been found in cartilage. As it has no blood vessels, it derives its nourishment by imbibition of

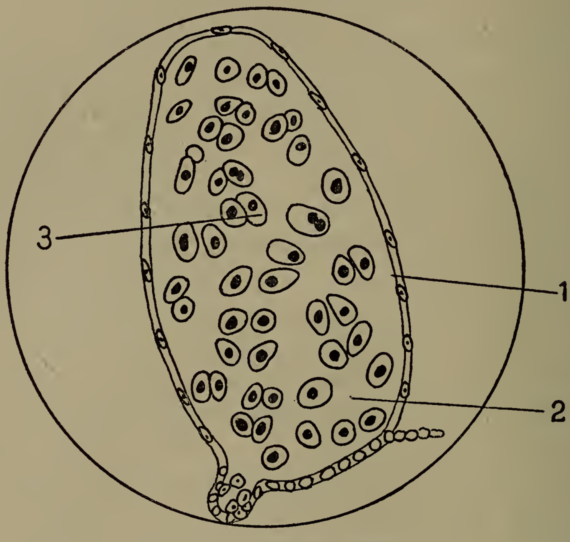


FIG. 20.—HYALINE CARTILAGE.
1. Perichondrium. 2. Matrix. 3. Cartilage cells. (Brinckley, C. W. B.)

lymph which exudes from the neighboring capillaries; i. e., from those of the perichondrium, or from the vessels of the synovial interarticular cartilage. Cartilage has an investing vascular membrane composed chiefly of white fibers, called the perichondrium. This membrane is found in all cartilage; under the microscope cartilage is seen to be made up of a ground substance, or matrix, in which are imbedded nucleated cells. The matrix is without distinct structure (homogeneous), or fibrous. This gives rise to two principal varieties, viz.: —

1. **Hyaline Cartilage.**—This cartilage receives its name from a Greek word meaning glass, from its clear appearance; has an almost structureless matrix resembling ground glass, in which the cells are imbedded in the patches of irregularly shaped cells. In the adult it occurs in the costal cartilage, the nasal cartilage, investing the ends of bones (Fig. 20), in articulations, in the larynx, the trachea, and the bronchi. In young animals it is found in a temporary form, which in time is replaced by bone through the deposit of lime salt.

2. **Fibro-cartilage.**—In this the matrix has a well-marked fibrous structure. The varieties are:—

a. Yellow Elastic Cartilage.—In this the matrix consists of fine interlacing elastic fibers, in which are imbedded numerous oval-shaped cells, each having a well-marked nucleus and nucleolus. It is more flexible and tough than hyaline cartilage. It is found in the cornicula of the larynx, the epiglottis, the Eustachian tube, and the external ear.

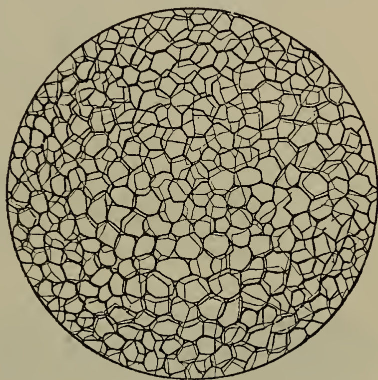


FIG. 21.—CELLULAR ELASTIC CARTILAGE FROM EAR OF MOUSE. (Brinckley, S. D. O.)

b. White Fibro-cartilage.—This in structure closely resembles the yellow variety, but has fibers which closely resemble those of the white fibrous tissue.

It is found in (1) interarticular cartilage, as the knee-joint; (2) in the marginal cartilage around the rim of the shoulder and hip joint; (3) in connecting cartilage, as in the intervertebral fibro-cartilage; (4) in sheaths of tendons.

Uses of Cartilage.—Cartilage has a number of important uses. It binds bones together, and yet allows a certain degree of movement, as in the vertebræ; it affords attachment for muscles and ligaments; it deepens joint cavities, as in the acetabulum; it gives firmness, protection, and support, as in the pinna, the larynx, the chest; it maintains the shape of

FIG. 22.—TRANSVERSE SECTION OF COMPACT BONE (of Humerus).

Three of the Haversian canals are seen, with their concentric rings; also the lacunæ, with the canaliculi extending from them across the direction of the lamellæ. The Haversian apertures were filled with débris in grinding down the section, and therefore appear black in the figure which represents the object as viewed with transmitted light. The Haversian systems are so closely packed in this section that scarcely any interstitial lamellæ are visible. x 150. (Sharpey.)

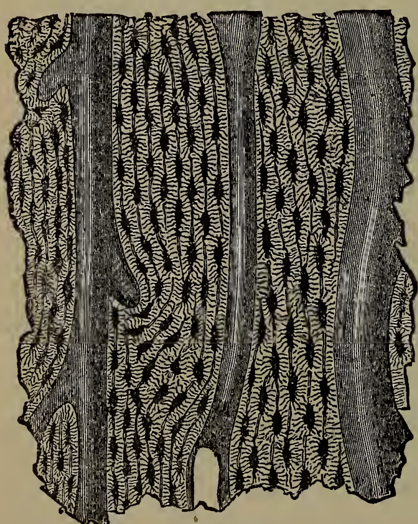


FIG. 23.

Longitudinal section from the human ulna, showing Haversian canals, lacunæ, and canaliculi. (Rollett.)

tubes, as in the trachea and the bronchi; it acts as a cushion to deaden shocks, as between interarticular cartilage; and lessens friction, as in articular cartilage of the long bones.

C. Bone and Dentine.—While these two substances resemble one another in composition and firmness, they differ very much in their structure, origin, and function. We shall defer this study until we come to them in their respective places.

V. The Nutritive Tissue.— The nutritive tissue is composed of the blood and the lymph. The blood is the liquid which circulates through the veins, arteries, and capillaries. It is composed of a liquid (plasma) in which float microscopic bodies (corpuscles). Its chief function is to carry food material to, and waste products from, the tissue.

The lymph is very much like the blood in composition, but has no red corpuscles.

The lymph bathes the tissues, and removes waste products which find their way to the blood vessels by means of the lymph veins.

CHAPTER III.

ANATOMICAL ELEMENTS.

EXPERIMENTS.

1. Carefully tease out some of the fleshy part (pulp) of an apple, mount in normal saline solution, and examine with a low power (one-half or three-fourths objective). Of what is the flesh of the apple composed? Make a drawing of the cells, and carefully note their structure. Treat with a weak solution of iodine, and again examine. What difference do you note?

2. Make a very thin transverse section of the pith of an elder-stem. Place on a glass slide, with a drop of water or glycerin, and examine, first with a low power, and then with a high power. Of what is the pith composed? Have you seen anything similar to what you observe in the pith?

3. Make a thin section of the dandelion (*Taraxacum*) stem, and put into a forty-per-cent solution of alcohol; then into sixty- and eighty-per-cent, keeping the section in each solution thirty or forty minutes. Put twenty or thirty drops of picrocarmine solution into a watch crystal. Place in this solution the sections, and let them remain until they are well colored, which will require from fifteen to twenty minutes, after which transfer them to ninety-per-cent alcohol, and let them remain there from ten to thirty minutes. Next place the sections in spirits of turpentine for five or ten minutes; watch them carefully, and if they shrink or curl up at the edges, remove them at once. Take a clean glass slide, and place near its center a drop of dammar or Canada balsam. Place on this one of the sections. Take a clean cover glass by the points of the forceps, and place it over the section so that the opposite edge of the cover glass will touch first, and lower it gradually, to avoid the formation of air bubbles underneath. Gently press down the cover glass. Examine with a one-sixth objective. Observe (1) the bounding membrane (*cell wall*), (2) the granular substance within the wall (*protoplasm or cell body or cytoplasm*), (3) a more

highly colored part (*nucleus*), (4) a point within the nucleus (*nucleolus*).

4. With a horn spatula or ivory paper knife scrape the back of the tongue or the inside of the cheeks or lips. Place the substance thus obtained on a clean slide, and cover with a cover glass, adding a drop of water if needed. Examine it with the microscope, using one-fourth or one-sixth objective, and make a drawing.

5. Examine in a normal salt solution with a high power the hairs which grow upon the stamens of the Spiderwort (*Tradescantia*). Try to determine the parts. Note the protoplasm, forming a layer lining the wall, heaped up around the nucleus, and sending off fibrous-like processes to various parts of the cell. Notice the currents of granular substance in the fibers, sometimes from the nucleus, sometimes toward it. What property of protoplasm do you learn from this experiment? Warm the slides as directed in the Appendix. Increase the temperature, and notice the effect.

6. Place a drop of water containing amœbæ on a slide; cover with a cover glass, being careful to avoid pressure, and search over it with a one-fourth-inch objective; if you find an amœba, examine it with a one-eighth-inch objective. Observe its outline, structure, and movements. Make drawings of it at intervals of five seconds or more. Describe what you see. What do you learn of the properties of the cell from this? Heat the slide as directed above, and note the effect.

Amœbæ may be found in mud, stagnant water, or in vegetable infusions.

7. Prick your finger, press out a drop of blood, and spread it out on a slide under a cover glass, avoiding pressure; then surround the margin of the glass with vaseline or oil. The white corpuscles may be recognized by their larger size, and by being less numerous. Observe their size, structure, form, and movements.

Make drawings of the more remarkable forms which they assume. In order to keep the colorless corpuscles so that they will retain their vitality and movement, it is necessary to keep the glass slide warm. This may be done by the method given in the Appendix. The blood of man should be kept at a temperature of 38° C.

8. Get a number of frogs' eggs or snails' eggs, and put

them in water in a warm place, and carefully note by means of the microscope the changes which take place. What do you learn by this of the properties of the cell? of its relation to tissues? of the origin and development of the animal?

9. Get from a pond or a brook some stagnant water. It will usually contain a great number of little plants and animals. Keep them in water in a warm place, and in the sunlight, and observe them from day to day. Write a description of the things you have seen. What do you learn from this experiment?

10. Secure some fish eggs; tease out the mass, and stain

FIG. 24.—GELATINOUS TISSUE OF INFRA-ORBITAL FOSSA OF RABBIT.

a. Bundles of connective tissue. *b.* Flat branched cell. *c.* Branched cell seen from the side. *d.* Cell of doubtful origin. (Sanderson.)

a number of eggs by placing them in picrocarmine, and then examine them with a high power. Make a drawing of the nucleus in the different specimens examined.

11. Secure some of the pollen of the wild onion; color it with picrocarmine, and examine it with a high power. Make drawings of what you see. In this experiment and in Experiment 10 you may be able to observe the nuclear division described on page 41 (Fig. 30).

12. Get a piece of a large ligament (*ligamentum nuchæ*), (*a*) tease it out as fine as possible in water, and examine a

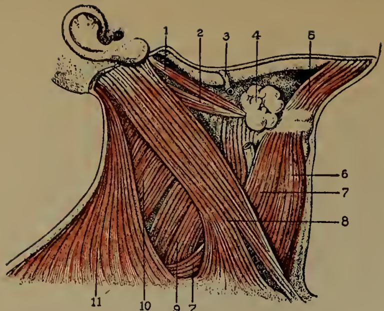


Fig. 35

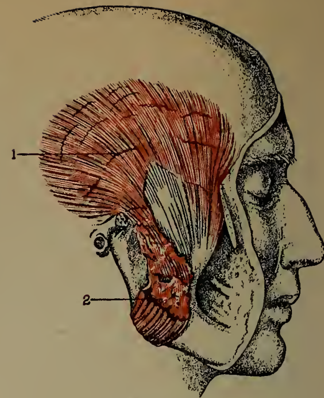


Fig. 37 a

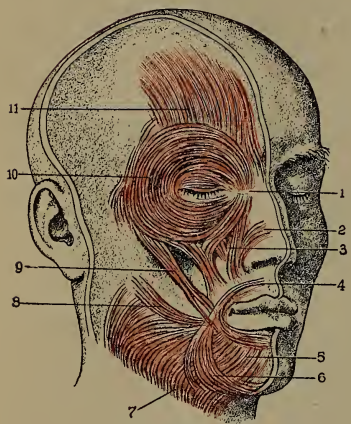


Fig. 36

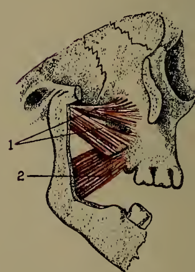


Fig. 37 b

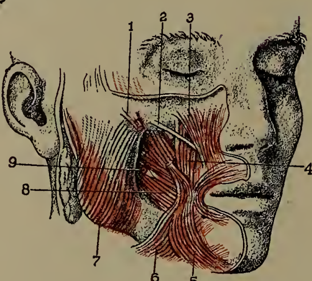


Fig. 38

PLATE II.

FIG. 35.—MUSCLES OF THE NECK.

1. Stylo-hyoid. 2. Digastric (posterior body). 3. Duct of Maxillary gland. 4. Submaxillary gland. 5. Digastric (anterior body). 6. Sterno-hyoid. 7. Omo-hyoid. 8. Sterno-cleido-mastoid. 9. Scaleni. 10. Splenius. 11. Trapezius.

FIG. 36.—MUSCLES OF THE FACE.

1. Tarsal ligament. 2. Nasal. 3. Quadratus labii superioris. 4. Orbicularis oris. 5. Quadratus labii inferioris. 6. Depressor anguli oris (Triangularis). 7. Platysma. 8. Risorius. 9. Zygomaticus major. 10. Orbicularis palpebrarum. 11. Occipito frontalis.

FIG. 37 *A*.—MUSCLES OF MASTICATION.

1. Temporal. 2 Masseter.

FIG. 37 *B*.—MUSCLES OF MASTICATION.

1. External pterygoid. 2 Internal pterygoid.

FIG. 38. MUSCLES OF MASTICATION.

1. Zygomaticus major 2. Zygomaticus minor. 3. Levator labii superioris. 4. Levator anguli oris. 5. Triangularis. 7. Masseter. 8 Buccinator. 9. Duct of parotid gland.

small portion in water or glycerin. How are the fibers arranged? Do they branch? (*b*) Treat a teased piece with acetic acid. What change do you notice?

13. Mince up several pieces of the ligament you get for Experiment 12, and boil in water for some time. Set away to cool. What change has taken place?

14. Cut from a recently killed frog or rabbit a piece of the tendon that extends the toes. (*a*) Place for ten or fifteen minutes in a five- to ten-per-cent solution of common salt. This will enable the tendon to be more easily teased. Tease as fine as possible. Mount in water or glycerin, examine with a high power, and observe carefully the arrangement of the fibers. Compare this observation with Experiment 12. (*b*) Treat a teased portion with acetic acid. What change do you note? Compare the action of acetic acid in this case with that of (*b*) in Experiment 12.

15. Clip a number of pieces of tendons; boil them in water for several hours, and set them away to cool. How does the result you get compare with that of Experiment 12?

Name three ways in which yellow elastic tissue differs from inelastic tissue, as shown by the experiments you have tried. Which of these is best adapted for attachments of muscles? which for ligaments? which in ligaments where great freedom of motion is required? How could you show that both elastic and inelastic fibers are present in a tissue? By your test (*b*) of Experiments 14 and 15, test the tissue that binds muscles, the lower layer of the skin, the coats of the aorta, the tendons of the muscles, a thin slice of cartilage.

ANATOMICAL ELEMENTS.— TEXT.

A muscle, a nerve, or the skin seems to be a simple structure, but an examination with the microscope shows it to be very complex.

As we have already learned, these organs are made up of simpler parts called tissues. The tissues, on examination, are found to be composed of still simpler parts. Most tissues may be reduced to two or three simple elements: one, a structureless, thread-like body — the fibers; the other, a more or less spherical body — the cell, bound together by a cementing substance, or matrix. Since these two structures

enter into the make-up of the various tissues of the body, they are called anatomical elements. While these structures are microscopic in size, they are very important, and deserve our careful study.

The Cell.— From our observation we have already learned that cells differ greatly in size, form, and structure. Corresponding with this difference of structure and composition will be found a difference of function and properties. We shall find it true throughout the whole organic world that a difference of form implies a difference in physiological action. As saws, knives, and chisels vary in form to adapt them to different uses, so cells differ that they may do different work.

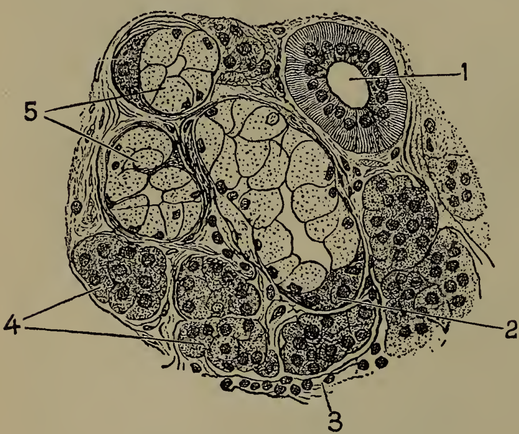


FIG. 25. GLANDULAR TISSUE.
Section of part of submaxillary gland (human). 1. A duct. 2. Crescent cells. 3. Blood vessel. 4. Serous cells. 5. Mucous cells.

The typical form of the cell is spherical, as seen in the egg of the frog or the snail. In process of the development of the plant and the animal, they become greatly modified from inherent forces or external cause, as pressure or similar influences. We have observed the globular and the flattened cell (Fig. 26) in drops of saliva; columnar, in various parts of the mucous membrane (Fig. 10); columnar with the free portion provided with hair-like processes (*cilia*) (Fig. 9), as in the mucous membrane of the nasal fossæ, upper part of the pharynx, the trachea, the lungs, and other parts of the body; fusiform, in the cells of the involuntary muscles (Fig. 15); stellate, in some nerve cells (Fig. 83); pear-shaped, as in the cells of the ganglion of the spinal nerve; flask-

shaped, in the goblet cells (Fig. 26) of the mucous membrane; fibrillated, in the skeletal muscle (Fig. 14); and caudate, with numerous branches (poles), some of which branch into numerous tree-like branches (arborescent) (Fig. 85). Cells vary in size from $\frac{1}{3500}$ to $\frac{1}{300}$ in diameter, and $\frac{1}{5000}$ to one-half inch or more in length.

Fig. 26.—Goblet Cells from Mucous Membrane of Stomach.

While cells under low power seem to be very simple, under high power they appear very complex. Typically, the cell (Fig. 32) consists of an investing membrane (*cell wall*); of a firmer part, making up the greater part of the cell, the body substance (*cytoplasm*), in which we recognize a more or less opaque network (*spongioplasm*), inclosing and ramifying a clear fluid substance (Fig. 32) (*hyaloplasm*). Near the center of the protoplasm is a spherical firmer portion,—*the nucleus*. By special preparation we find the nucleus is composed of a clear fluid called *nucleoplasm,* and a network of fibers called *chromoplasm*. In the nucleus of many cells is to be found one or more small points called nucleoli.[1]

---

[1] *Physical Structure of Protoplasm.*—Although this subject has received extended and careful study, and with the aid of improved histological methods, yet we are still much in doubt as to the structure of protoplasm. While histologists are generally agreed as to the appearance and the parts of protoplasm, as seen under high power, they are not agreed as to the interpretations of the appearance. Under very high power, and by proper staining, protoplasm appears as a meshwork, composed of fine granules suspended in a clearer substance, the spaces of the meshes being composed of a third clearer substance.

The three more important interpretations of this appearance are, (1) "that protoplasm is composed of a clear, viscous substance, in which are imbedded many fine granules of denser substances and numerous larger globules of a clearer, more liquid substance;" (2) "that the fine spots, which appear to be granules, are simply cross-sections of fine threads of denser protoplasm which lie coiled and tangled in the clearer protoplasm;" (3) "that protoplasm exists as a framework, being a viscous liquid containing many fine globules of a liquid of different density and numerous larger globules of a fluid of still other density." The foam does not consist of bubbles filled with air, but of protoplasm of different density. The last theory is the one more generally accepted by the majority of modern naturalists.

We are even more in doubt as to the chemical constitution of protoplasm than we are as to its physical structure. We thus know little of the real nature of protoplasm, which is considered to be the fundamental life substance.

Histologists are not agreed as to the nature of the nucleoli. Some consider them as knots formed by the crossing of the meshes of the chromoplasm, while by others they are considered as a distinct structure. *Most animal cells are without cell walls.*

There are some cells so simple that they seem to be devoid of cell wall and nucleus, and consist only of protoplasm, as seen in some of the so-called animals, as the *protomyxa.*

While the cells in the different tissues vary in their composition, they consist primarily of from eighty to eighty-five

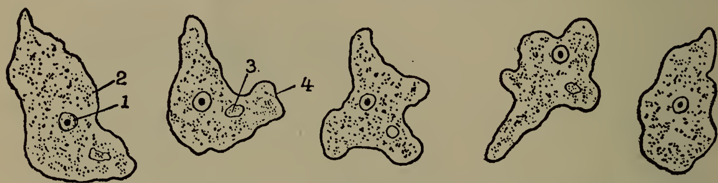


FIG. 27.—FORMS ASSUMED BY AN AMŒBA IN THIRTY MINUTES' OBSERVATION. As the coverings protrude, the protoplasm seems to flow with the projecting part and backward again as the projecting part retracts. (Brinckley.) 1. Nucleus. 2. Granules. 3. Vacuole. 4. Cell wall.

per cent water. The solids consist chiefly of proteids, the principal one of which is plastin; of carbohydrates, the principal of which is glycogen, a kind of starch; and of mineral salts.

We can best learn the properties of the cell by the careful examination of a little microscopic animal, the amœba (Fig. 27), or the white corpuscles.

The amœba consists of a single cell, and to live it must move, breathe, digest, secrete, excrete, etc.; and yet we find no special parts for these functions, but all parts of the cell seem to have their respective functions.

From a careful study of this little animal we learn, (1) that cells have the power to be awakened to action, i. e., have irritability; (2) that they may change their form — contract; (3) that they can appropriate material, and make it like their own substance — assimilate;[1] (4) that they can

[1] Protoplasm also has the power of taking up some substances and rejecting others. This power to select one substance and reject others is called *selective absorption.* This explains, in part, why a drug will affect one tissue and

do chemical work by making compounds; (5) that they have the power of forming by their division, either directly or indirectly, new cells.

When the animal is composed of many cells, the work of living becomes divided, some cells taking upon themselves the whole work of contraction, some that of feeling, some respiration, some digestion, and some excretion and secretion.

In the human body we have the muscle cells for contraction, the nerve cells for feeling, those of the lungs for respiration, those of the alimentary canal for digestion, and those of the kidneys for excretion.

The cells' taking upon themselves some part of the work of living is called *division of labor.* To better enable the cells to perform their respective work, we find them differing in form and structure. The changing of the cells from a simpler to a more complex form and composition is called *differentiation,* and it is a well-established biological principle that the differentiation of form (*morphological differentiation*) is accompanied by differentiation of function (*physiological differentiation*).

Metabolism.— All the activities of the body must be brought about by the activity of the cell. It is the only vital part of the body, the other parts being mere skeletal structures.[1]

---

not others; why one drug will be a cerebral stimulus and another a vasomotor. Thus it is that the blood stream, laden with mineral salts, passes the muscles unaffected, but in passing through the bone tissues loses part of its calcium phosphate and calcium carbonate.

[1] In its development the frog's egg passes through the following stages: —

1. The protoplasm within the cell wall divides into numerous cells, and at each subdivision the cells become smaller, passing through what is called the *segmentation stage.* (Fig. 31.)

2. As a result of this continued segmentation, there is formed a body which has the appearance of a mulberry, and hence is called the *morula stage* (Fig. 31), in which the cells become crowded to the outer part of the inclosing capsule.

3. Following this later stage, the cells in the upper part become somewhat different from those of the lower part, and the sphere becomes pitted (resembling Fig. 31), when it is known as the *gastrula stage.*

4. The cells continue to multiply, and form a body (like *e*, Fig. 31), in which there are three well-marked cell layers, differing in the form and size of the cells composing them. The body is now known as the *blastoderm,* and consists of the upper

It is in the little laboratory of the cell that are manufactured the various materials of the body. It is the cell that does the work of secretion and of excretion; that is the

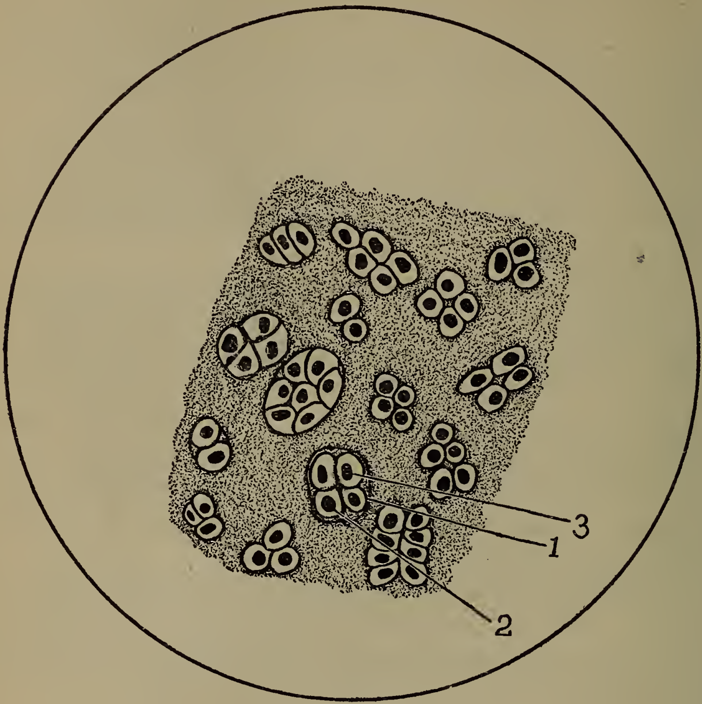


FIG. 28. — INTERNAL CELL DIVISION.

Hyaline cartilage from the toe of a chicken. 1. Old cell wall. 2. New cells. 3. Nucleus. (Brinckley, C. W. B.)

source of the energy of the body, whether it be motion, heat, or nerve stimulus.

The varied activity by which the cells perform this function is called *metabolism*.

---

layer of cells, called the *epiblast;* a middle layer of cells, the *mesoblast;* and the lower layer of cells, the *hypoblast.*

From the epiblast are formed the skin (epidermis), the nervous system, and organs of special sense (in part); from the mesoblast is formed the skeleton, muscles of circulation, connective tissue, the true skin (*derma*), the spleen, the kidneys, and the bladder (except the lining, which is derived from the hypoblast); from the hypoblast are formed the mucous membrane, the alimentary tract, the liver, the pancreas, and the lungs.

When the process is constructive in its effect, i. e., tends to build up living material, or when complex substances are made from those that are simpler, it is called *anabolism.* The breaking down of complex substances into simpler ones, by which potential energy is converted into kinetic energy of motion or heat or life force, is called *katabolism.*

The process by which the meat, the bread, the butter, and the fruit we eat is converted into muscle, nerve, bone, and brain tissue is anabolism. That by which the tissue uses up material to produce motion and heat, and by which the waste products, carbon dioxide, urea, and water, are produced, is katabolism.

FIG. 29.
Leucocyte of Salamander larva, showing attraction sphere (the centrosome with its radiating filaments). (After Flemming.)

Cell Multiplication.— As we have already seen, cells have the power of producing new cells. When the cells produced are destined to become new individuals, the process is called *reproduction;* when they are to form new tissue, and augment the size of the body, the process is called *growth.*

The principle that all cells proceed from pre-existing cells, is the basis of biological science. The body of all animals or plants consists either of one cell or of many cells and their products.

Cells multiply in various ways, the most common of which are *direct cell division, internal cell division,* and *indirect cell division.*

Cell Division.— The division of the cell is preceded by division of its nucleus.[1] Nuclear division may be either (1) simple, or direct (*amitotic*), which consists in the simple

[1] *The Centrosome.*— This is a little body which is continually present with the nucleus. The centrosome possesses a peculiar attraction for the protoplasmic filaments and granules in its vicinity, producing a stellate appearance, like Fig. 29. The centrosome, with the attracted filaments, is called the *attraction sphere,* and plays a very important part in the division of the nucleus, but it is not probably the first cause of the process of division.

exact division of the nucleus into two equal parts by constriction in the center, and may have been preceded by the division of the nucleoli; or (2) indirect (*miotic*), which consists in a series of changes, the complexity of which varies in different cells.[1]

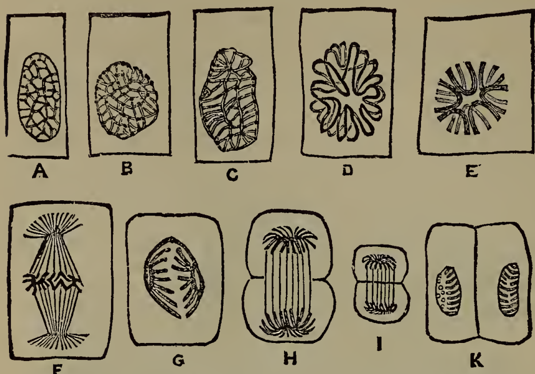


FIG. 30.—INDIRECT CELL DIVISION (*Karyokinesis*).

A. Ordinary nucleus of a columnar epithelial cell. B, C. The same nucleus in the stage of convolution. D. The *wreath* or *rosette* form. E. The *aster*, or single star. F. A nuclear spindle from the Descemet's endothelium of the frog's cornea. G, H, I. *Diaster* stage. K. Two daughter nuclei. (Klein.)

FIBERS.

Kinds of Fibers.— Fibers are of two kinds, *yellow* and *white*. Yellow fibers have a yellow tinge, are very elastic and often give off branches, and anastomose with other fibers. They give firmness and elasticity to the parts in which they are found. They make up the greater part of many tendons; are found in the middle coats of the arteries, the pulmonary alveoli, and in various parts of the body in connection with white fibers. They vary in size from $\frac{1}{8000}$ to $\frac{1}{2400}$ of an inch in diameter. On boiling

[1] In most cells these changes are as follows, as observed by Klein: 1. The nucleus in the resting conditions consists of a very close meshwork of fibrils (chromoplasm) imbedded in protoplasm (nucleoplasm), and surrounded with an envelope. 2. The enlargement and disappearance of the envelope, and the increase in thickness of the nuclear fibrils, which, being more separated, stain better (stage of convolution) (Fig. 30). 3. The arrangement of the fibrils into some definite figure by an alternate looping in and out around a central space, forming a rosette or wreath (rosette or wreath stage). 4. The loops of the rosette now become divided at their circumference, and their central points become more angular, so that the fibrils divide into portions of about equal length, as if doubled at an acute angle, and radiate V-shaped from the center, forming a star or wheel, or, in some cells, from two centers, forming a double star (diaster) (the aster stage). 5. After remaining almost unchanged for some time the V shape being rearranged in the center, side by side, point of V outward, tends to separate into two bundles, which gradually assume position at either pole (nuclear spindle stage). 6. From these groups of fibrils the two nuclei of the new cells are formed (daughter nuclei stage). The stages through which they pass before reaching the resting condition are just the same as those passed through by

they do not yield gelatin, but a substance called *elastine*. They are unaffected by acetic acid.

White fibers, when forming a compact tissue, as a tendon, have a shining, pearly appearance, are very strong, and pliant, and inelastic. When examined with a high power, a teased specimen of a small bundle of white fibers is seen to consist of very fine transparent fibers of from $\frac{1}{50000}$ to $\frac{1}{25000}$ of an inch in diameter. These fibers do not occur

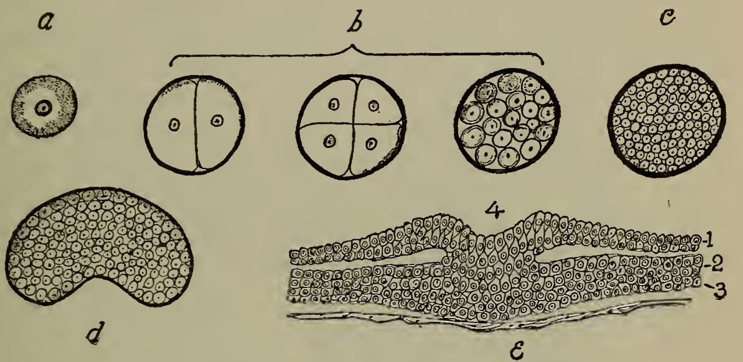


FIG. 31.—STAGES OF DEVELOPMENT.

a. Ovum. *b*. Segmentation stage. *c*. Morula stage. *d*. Gastrula stage. *e*. Blastoderm. 1. Epiblast. 2. Mesoblast. 3. Hypoblast. 4. Primitive groove (Brinckley.)

singly, but are cemented by a quantity of the mucin ground substance; in contrast with the yellow fibers, in which each fiber of a bundle seems parallel with its adjoining fibers, neither branching nor uniting with them. While transparent with transmitted light, when seen in mass they appear white. Acetic acid causes them to swell, and become almost invisible. On boiling with water they yield *gelatin*.

They are found in the wavy bundles of areolar tissue;

---

the original nucleus (*mother nucleus*), but in reverse order; viz., the star, the rosette, and the convolution. During or soon after the formation of the daughter nuclei, the cell itself becomes contracted, and then divides in a line about midway between them. These changes will be clearly understood by a careful study of Fig. 30. It is now believed that the indirect nuclear division (*miotic*) is very nearly universal, if not entirely so. Many cells are being formed every moment of our lives to keep up the growth of the bódy, and to supply those that become transformed. The changes which we have described in nuclear division are taking place continually.

in parallel bundles to form compact bundles or cords, as in tendons and ligaments: they form fibrous membrane, as the *periosteum,* covering the bones; the *perichondrium,* covering the cartilage; the *dura mater,* lining the skull; and the *fasciæ,* enveloping and binding together the muscles. In the true skin and mucous membrane the bundles of interlacing white fibers form a close felt-work.

White and yellow fibers generally occur together in tissues, and the relative proportion of each will in a large degree determine the property of the tissue; the white fibers giving firmness and inelasticity, and the yellow elasticity.

As to how these fibers originate, histologists are not agreed. Some think they are formed by the modification of the substance which the cells throw out between themselves, known as intercellular substance; others that they are modified forms of branched cells, the branches of which have become joined and then reduced.

CHAPTER IV.

THE MUSCULAR SYSTEM.

EXPERIMENTS AND DEMONSTRATIONS.

1. Place the arm on the table so that it rests on the forearm. Grasp the upper part of the arm with the left hand, and gradually bend the arm. What change do you note in the muscle? Let the arm return gradually to its first position. What change do you note? The first condition is called a contraction, the second a relaxation.

2. Straighten the arm, grasp it so that the fingers will press upon the upper part of the arm, and the thumb upon the lower. Gradually bend the forearm, and notice what change takes place in the upper muscle of the arm and also in the lower. Extend the arm. What change do you note in the biceps? How does it compare with the first condition? Try other muscles. What does this teach you in regard to the arrangement of muscle?

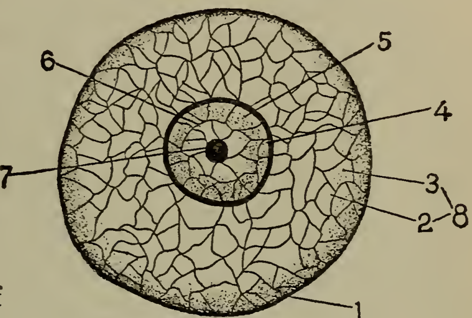


FIG. 22.—TYPICAL CELL. (Ideal.)
1. Cell wall. 2. Reticulum (Spongioplasm). 3. Paraplasma (Hyaloplasm). 4. Membrane of nucleus. 5. Nucleoplasm. 6. Chromoplasm. 7. Nucleolus. 8. Cytoplasm.

3. Obtain a rat or a cat, and prepare it for dissection. (See Appendix.) Remove the skin, and carefully notice appearance and arrangement of the flesh (*muscles*). Carefully dissect off the covering (*fascia*). To what are the muscles attached? How are they connected? Of what two parts are some of the muscles composed? (See Fig. 48.) Examine the nature of the tendons. What advantage does it give the muscle for the tendons to be inelastic?

4. Remove the muscle (the muscle should be fresh) of the calf of the leg. Attach one tendon to a firm support, and to the other tendon fasten a weight, gradually

increasing the weight. Is there any change in length? Remove the weight. Does the muscle return to its former length? What property does this show the muscle to possess? Try the same experiment with a muscle that has been killed by immersing it in water at 40° C. (140° F.).

5. Examine the muscles for the different modes of arrangement of the tendons. Make drawings of what you observe, and compare them with those given in Fig. 34.

6. Examine carefully the tendons of the muscles dissected. Pull on the tendons to determine their action. Dissect out the muscles of the leg of a cat or a chicken. Notice how the tendons work.

7. Dissect out one of the muscles of the leg of a frog. Tie it by its tendons to a stick, so that it will remain extended. Preserve by keeping in alcohol (80 per cent). Tear off a small piece, and tease it out as fine as possible in dilute glycerin. Examine under high and low power. Note, (*a*) the varying size of the threads (*fibers*); (*b*) the marking of the fibers (*striation*), which under high power are seen to be made up of alternate dim and bright crossbands. (*c*) Do the fibers break up into finer threads (*fibrillæ*)? (*d*) Treat a specimen in a similar manner that has been preserved in picric acid. Do the fibers break up in more than one direction? Examine the surface of the disks. Make drawings of your observations, and compare them with those in this book.

8. Remove the covering of a frog's muscle, and tear off a small portion of the flesh. Tease so as to show the fibers. Press on some of the fibers with a bristle; this will break the muscle substance, and leave uninjured the delicate covering (*sarcolemma*) of the fiber.

9. To fibers teased the long way of the muscle, add a five-per-cent solution of acetic acid. Note the changes that take place. When the fibers have become transparent, notice the numerous dots (*nuclei*) scattered throughout the muscle substance. Make a careful drawing of their appearance.

10. Imbed in paraffin a small piece (a cross-section of a muscle) which has been hardened in a five-per-cent solution of chromic acid; make a thin transverse section, stain in hæmatoxylin, and mount in glycerin. Observe, (*a*) the connect-

ive tissue (*epimysium*) which surrounds the bundles of fibers and the whole muscle, which gives off connective tissue (*endomysium*) between the muscle fibers; (*b*) the relation of the nuclei.

11. From the peritoneum of the intestine of a recently killed animal tear off with fine forceps a piece as thin as possible of the longitudinal muscular coat. Put in a one-per-cent solution of potassium dichromate or in a thirty-per-cent solution of alcohol for two days, wash with water, stain in picrocarmine, wash to remove excess of coloring, tease out in dilute glycerin. Note, (*a*) the form and arrangement of the muscle cells; (*b*) the arrangement of the fibers.

12. Treat a piece as in Experiment 9, teasing it out in a normal salt solution. Examine it, and then add a one- to five-per-cent solution of acetic acid, and note the change in the appearance of the cells.

13. Take a small piece of the heart of a frog or a rat, and preserve it in potassium dichromate solution. Take a small piece, tease it out thoroughly, and mount in glycerin. Carefully observe, (*a*) the form, size, and arrangement of the cells; (*b*) that the fibers have no sarcolemma. (*c*) Stain some of the teased fibers in picrocarmine to make the nuclei more prominent. (*d*) Note the branching of some of the cells.

14. Destroy the brain and spinal cord of a frog, and expose the sciatic nerve, at about the upper third of the thigh, where the artery (*femoral*) gives off two transverse fibers, from point down to the knee; isolate the nerve by cutting away the connective tissue. Care should be taken not to injure the nerve by pinching it, or by putting too great a strain upon it, and also not to injure the artery.

Take a pair of electrodes which have platinum points on one side, and connect with two Grenet cells connected in series; interpose a key so as to short-circuit the current (Fig. 33). Close the circuit. Place the electrode under the nerve so that the electrode alone touches it. Notice that, in only very rare cases, there is movement of the muscles when the circuit is opened and closed. Do not repeat the experiment more than once or twice, as it tends to exhaust the nerve, and render it unfit for the other experiments for which you will need this preparation.

What is the effect of a constant galvanic current?

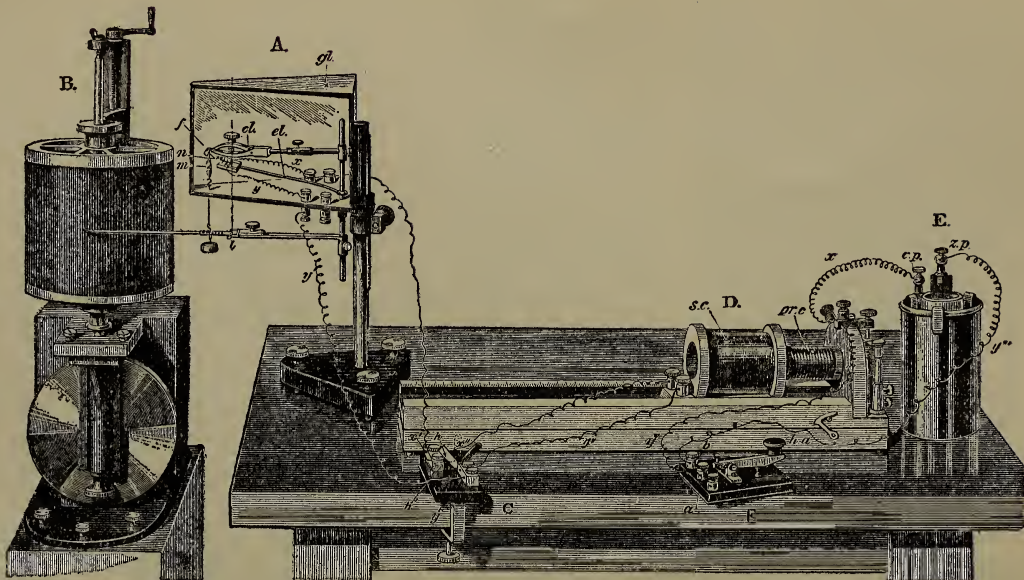


Fig. 33.—Muscle Curve Apparatus.

A. Moist chamber. *cl.* Clamp. *f.* Femur. *n.* Nerve. *m.* Muscle. *x* and *y.* Wires from key at *c.* *l.* Lever to make tracing on cylinder of the kymograph. B. Kymograph with cylinder covered with smoked paper. C. Du Bois Reymond's Key. D. Induction coil. *s. c.* Secondary coil. *pr. c.* Primary coil. E. Battery. *c. p.* Wire from carbon plate (positive electrode). 3. *p.* Wire from zinc plate (negative electrode). F. Morse Key.

15. Introduce into the circuit of Experiment 14 an induction machine, having primary and secondary coils (see Fig. 33). Open and close the key several times. Notice, (*a*) that each closing and opening, which produces a single induction, causes a single contraction of the muscle. Do not use too strong a current; begin with the weaker current, and generally increase by the means of the secondary coil, pushing it farther in the primary to increase the current, until you get a well-marked contraction. (*b*) Open and close the keys as rapidly as you can for a few seconds, which produces a continual contraction (*tetanus*) of the muscle. Open the circuit, and notice the flaccid condition of the muscle.

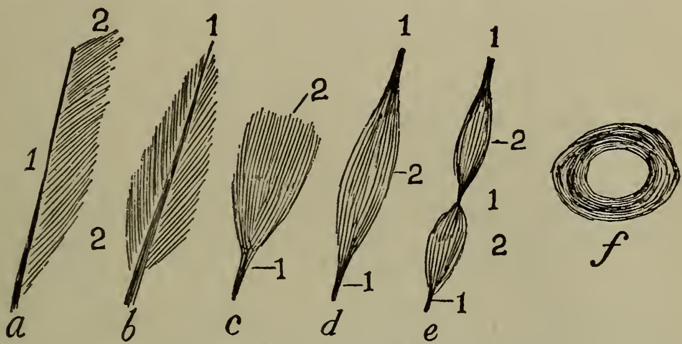


FIG. 34.—FORMS OF MUSCLES.
a. Penniform. *b.* Bipenniform. *c.* Radiate. *d.* Fusiform. *e.* Digastric. *f.* Sphincter. 1. Tendon. 2. Body.

16. Expose the sciatic nerve well up the thigh, and cut it off as high as you can. Dip the free end of the nerve into a saturated solution of common salt (*sodium chloride*). Notice the effect. How has the solution acted?

17. Take the preparation of Experiment 16, and cut off the portion of the nerve that was in that solution. Pinch the end of the nerve several times with the forceps. Notice the contraction.

Anything which calls into action or increases the activity of an organ is called a *stimulus*. From the above experiments, how many ways have you found of stimulating muscles? Can you think of any other way by which they can be stimulated? By what stimulus are most of the movements of the body produced?

18. Dissect out the calf muscle (*gastrocnemius*) (Figs. 46 and 47), so as to leave it attached to the head of the

thigh bone (*femur*), and leave the sciatic nerve intact. Remove the bone from its socket (*acetabulum*) in the hip bone (*innominatum*), and cut off the bone about an inch from the upper end. Now cut off the sciatic nerve as high up as possible, being careful not to strain or stretch it. Prepare the apparatus as shown in Fig. 33. Load the lever with ten or twenty grains, and bring it in contact with the cylinder of the kymograph, which has been covered with a piece of smoked paper.

Arrange the induction machine so as to produce a single induction shock. Set the cylinder of the kymograph to rotating rapidly; note carefully the effect produced by the lever tracing on the smoked paper when the muscle contracts. The tracing is called a muscle curve. Make several tracings. Carefully remove the smoked paper, and put it into a shallow pan containing a solution of shellac and alcohol; carefully remove and let it dry. This will make the tracings permanent, so they can be examined without injuring them. If you do not have a kymograph and moist chamber, fair results may be obtained by removing the handles from a seven-in-one apparatus, and putting in their place two spindles, the upper one ending in a cogwheel, so that it can be put in motion by clockwork or a weight. The lever for the muscle and the tracing may be fixed to a ringstand. The muscle-nerve preparation may be kept moist by occasionally spraying it with a normal saline solution. (See Appendix.)

20. With the same apparatus and preparation as in Experiment 19, see what effect rapidly repeated induction shocks have upon the contraction and the form of the curve.

From these experiments, how many changes do you notice in a muscular contraction? Does the muscle begin to contract the instant you apply the stimulus? Compare the phase of contraction with that of relaxation.

21. Remove from the thigh of a frog, as soon as possible after killing, the long, flat muscle called the *sartorius* (Fig. 45). In dissecting out the muscle, take great care not to injure the muscle except at its extremities. Place it at once in a normal saline solution in a glass vessel, and set it on an unheated stage. Put the part least injured under a two-thirds objective, and focus down on some object beneath or within the muscle; notice the ease with which it can be seen. Now gradually heat the stage by the apparatus as explained

in the Appendix. Carefully watch the temperature as determined by a thermometer placed in the solution containing the muscle. Carefully watch the effect of the heat upon the transparency of the muscle. Raise the temperature to 40° C., which kills the muscle substance, producing the result you have observed.

22. Divide a fresh muscle. Place one portion in water at 40° C., the other in water at 100° C. Test the reaction of both. The portion in 40° C. will be found to be acid, that in 100° C. to be alkaline. When muscle substance dies, it passes gradually into a state called *rigor mortis,* and in so doing becomes acid in its reaction. This is the case in the portion at 40° C. Rigor mortis is prevented by placing in water at 100° C.; the muscle therefore retains its normal reaction.

23. (*a*) Oppose the fingers and thumb, and note action of muscles. (*b*) Stand erect, and raise the hand as in pointing to an object; note action of muscles. Are there other than the arm muscle called into play? Take a position with a ball bat held in your hands as in striking a ball. What do you learn in this experiment about the harmony of action of muscles?

24. Grasp the handles of an induction machine, gradually increase the current by means of the core of the secondary coil, and carefully note the effect on the muscles. If there is a strong current, try to let go of the handle. Why can you not let go? In what condition are the muscles?

25. Place one of the metal handles in a basin of water. Place a coin in the water. Grasp that handle of the induction coil not in the water with your left hand. Put on a strong current, and try to remove the coin from the water with your right hand. Explain what takes place when the hand touches the water.

26. Have some one lift a heavy weight, and carefully notice the expression and condition of his body while lifting the weight. Try to lift a heavy weight yourself? What muscles are called into play? Why do you hold your breath? What effect has the lifting and the holding of the breath upon the pressure of the great blood vessels? How do you account for the flushed veins?

27. Note carefully the pulse and respiration of the person performing this experiment; then have him perform some

vigorous exercise, as running rapidly for a short time. What change do you note in the pulse and respiration? How do you account for this difference? Why should there be a "shortness of breath"?

28. Note your pulse and respiration before and after taking a moderate walk. What difference do you note? Why is the body not fatigued, and the pulse and respiration much increased?

29. Hold the arm out straight for two minutes, and notice the effect. Now alternately flex and extend your arm for the same length of time, making the movements moderate. How do you account for the difference in weariness produced in the two cases?

30. Let the arms hang at the side, and take the measure of the arm at its larger part. Flex the arm, and take the measure of the larger part. What difference do you notice?

31. Determine the attachment of the biceps muscle to the forearm by slightly flexing the forearm, and passing the finger from the upper surface of the elbow joint over the tendon that is tense to the point to which it is attached. To what bone is it attached? Determine the upper attachments by passing the finger over the shoulder joint, and notice what tendon is tense when the forearm is flexed. The tendon attached to the fixed point is called the *origin;* the tendon attached to the point of motion, the *insertion.*

32. In a similar manner determine the origin and insertion of the muscles that flex the hand; that flex the fingers; that extend the hand; the fingers; the forearm. Try similar experiments with other muscles. What advantage is secured by the muscles that move the hand having long tendons, and by the muscles being located in the forearm instead of in the hand?

33. Determine the position, origin, and insertion of the muscles of the thigh, leg, and foot. Make a record of your observations. Examine the illustrations, and determine the names of the muscles with which you have experimented.

34. Examine the skeleton, and see how the insertions and origins you have determined correspond with the prominence and markings of the surface of the bones. Compare your observations with the facts given in the diagram of the principal muscles. Can you give a reason for the prominences and markings on the bones?

35. Make an apparatus like Fig. 34*a*. Arrange the apparatus as in *A*. Put a four-ounce weight at the end of the short arm, and see what weight will balance it on the end of the longer arm. What is the ratio of the length of the arms as compared with the weights? What advantage is gained by this kind of lever? Read in the text the paragraph on mechanism of motion, and determine the class to which this lever belongs.

36. Examine the skeleton in connection with Figs. 43 to 47, and determine what bones form first-class levers.

37. Arrange the apparatus as in *B*, and put an eight-ounce weight two spaces from the hinge, and determine how many ounces it takes to balance the eight-ounce. What class of lever does this represent? What advantage is gained by this class of lever? What bones and muscles of the body are of this class of lever?

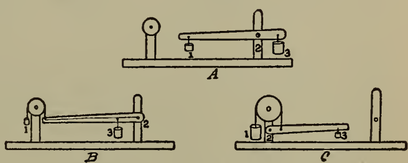


FIG. 34a.
A. 1. Power. 2. Fulcrum. 3. Weight.
B. 1. Power. 2. Fulcrum. 3. Weight.
C. 1. Power. 2. Fulcrum. 3. Weight.

38. Arrange the apparatus as in *C*, and put a two-ounce weight at the end of the lever and a sixteen-ounce weight upon the string, attached one space from the hinge. What class of levers does this apparatus represent? What bones and muscles of the body form this class of lever?

39. What class of levers do the following form: the head as it is bent backward by the complexi muscles? by the foot in flexion? by the leg in flexion?

40. Carefully dissect out the calf muscle of a rabbit. Cut it loose from its tendons. Weigh the muscle, place it in a drying oven, and keep it at a temperature of 110° C. for several hours until dry. Remove the muscle from the oven, and when cool, weigh, and determine loss of weight from drying. The loss of weight represents approximately the amount of water in the muscle. What per cent of the muscle is water?

If you do not have an "air-drying oven," the muscle may be dried on an evaporating dish or sand bath on the stove.

41. Put the dry muscle in a porcelain or platinum crucible, and heat it until the muscle is reduced to ashes.

Let the ashes cool, then weigh them. The weight of the ashes represents the amount of mineral in the muscle. What per cent of the muscle is mineral matter?

42. Dissolve the ashes in water, divide the solution into five parts, and test the respective portions for potassium, sodium, calcium, phosphates, carbonates, and chloride. (See Appendix.) Which of these substances gives the greatest amount of precipitates?

43. Soak fifteen or twenty grains of muscle in tepid water for four hours. Filter the solution, and test a portion for lactic acid (*sarcolactic acid*). (See "Tests" in Appendix.)

44. Take a dead muscle, remove all fat and tendons, and wash it in water until the washings give no trace of proteids; mince thoroughly, and treat with a ten-per-cent solution of common salt (ammonium or magnesium chloride may be used in place of the common salt), which dissolves out a viscid fluid. Filter the viscid liquid, and as it passes through the filter, let it drop into distilled water, in which it forms a white, fleecy precipitate (*myosin*).

See if the viscid fluid will dissolve in a ten-per-cent solution of common salt; in dilute muriatic (*hydrochloric*) acid; in picric acid or tincture of guaiacum. What color does it give in the last case? Is myosin a proteid? Test it for proteids.

THE MUSCULAR SYSTEM — TEXT.

The "Master Tissues."— The muscles and nerves have been very appropriately called the master tissues. Not only on account of the functions they perform, but also from the fact that most of the other tissues work to support these tissues. Note as we proceed in our study how and why this is the case.

Motion Essential to Our Being.— Food must be secured, digested, taken to the blood, the blood taken to the tissues, and then the blood returned to the excretory organs that the waste products may be removed. These, with the various other acts of the body, require motion.[1] In the amœba we found that the power of motion was equally distributed to

[1] *Mechanism of Motion.*—Many of the movements of the body are produced in the same way as in many forms of machinery,—by means of levers or a system of levers.

all parts of the body. In the higher animals, however, the work of motion is confined to one tissue, called the *contractile* or *muscular* tissue, which has the power of shortening, or *contracting,* and returning to its first condition, *relaxing,* and being attached to firmer parts, motion is produced. In most of the movements of the body the muscles are attached to firmer parts (*bones*), which act as levers, this making possible locomotion and various other movements. There are some few movements that take place in the body which are not dependent on muscles, as the movement produced by ciliated cells, and the migration of white corpuscles.

The Muscular System. — The muscles of the body make up what is called the flesh. The muscles, which are attached to the skeleton of the body, and by which its voluntary movements are produced, are called *skeletal muscles.*

A lever is an inflexible bar, free to move about a point called the *fulcrum.* The resistance to be overcome is called the *weight*, and the force acting to overcome or balance this resistance is called the *power.* From the relation which these parts bear to each other, levers are of three classes. When the fulcrum is between the weight and the power, the lever is of the *first class*; when the weight is between the power and the fulcrum, the lever is of the *second class*; and when the power is between the fulcrum and the weight, the lever is of the *third class.*

If the power applied is less than the resistance overcome, there is a gain of *intensity;* if the point to which the power is attached moves slower than the point to which the weight is attached, there is a gain of *velocity.* Intensity is the advantage sought in levers of the first and second class and velocity in the third-class lever; but in some instances, velocity is the advantage sought in the first-class lever, as in the hamstring muscle inserted to the tuberosity of the ischium, and originating from the posterior part of the knee joint, in which the muscle attached to the ischium is the power, the hip joint the fulcrum, and the trunk and head the weight. This muscle raises the body erect when bent forward. We have a good example of a second-class lever in the jaw; the jawbone being the lever, its articulation at the temporal bone the fulcrum, the masseter muscle the weight, and the genio-hyoid inserted to the interior of the tip of the chin the power. The forearm is a third-class lever; the ulna being the lever, the elbow joint the fulcrum the biceps muscle the power, and the hand and the object to be lifted are the weight.

By being of the third-class the forearm has greater freedom and speed of movement, and while there is a great loss of intensity, this is more than made up in the grace and velocity of the movements of the arm. The foot gives us an example of the three classes of levers: extending the foot, first-class; second-class when the body is raised on tiptoe; and the flexion of the foot, third-class.

Prove the statement in regard to the foot by determining the position of the fulcrum, power, and weight in each of the cases mentioned.

PRINCIPAL MUSCLES.

(See Plates II, III, IV, V, and VI.)

MUSCLE.	ORIGIN.	INSERTION.	FUNCTION.
Occipito-frontalis.	Superior curved line of occipital bone and angular process of frontal bone.	To muscles of eyelid and aponeurosis in front.	Moves the scalp, gives expression of surprise, and when much contracted that of fright or horror.
Orbicularis palpebrarum.	Internal margin of orbit.	Outer margin of orbit.	Closes the eyelids.
Levator palpebrarum.	Lesser wing of sphenoid.	Upper tarsal cartilage.	Lifts upper eyelid.
Corrugator supercilii.	Superciliary ridge of frontal bone.	Under surface of orbicularis palpebrarum.	Pulls eyebrow downward and inward; it is the "frowning" muscle and principal one in expression of suffering.
Levator labii superioris alæque nasi.	Nasal process of superior maxillary bone.	Alar cartilage of nose and to the upper lip.	Draws the wing of nose and upper lip upward. Chief muscle of nose. Chief muscles in expression of contempt and disdain
Dilator naris anterior.	Alar cartilage.	Border of wing (ala) of nose.	Dilates nostrils.
Dilator posterior.	Nasal notch of superior maxillary bone.	Skin at margin of nose.	Dilates nostrils; active in difficult breathing. Contracted in expression of anger.
Zygomaticus major.	Malar bone.	Angle of the mouth.	Angle of mouth backward and upward, as in laughing.
Zygomaticus minor.	Malar bone.	Outer part of upper lip.	Draws upper lip backward, upward, and outward. Gives to the face expression of sadness.
Levator labii inferioris.	Incisive fossa of inferior maxillary.	Skin of lower lip and the chin.	Raises and protrudes the lower lip, and wrinkles the skin of the chin. Gives expression of doubt or disdain.
Depressor labii inferioris.	External oblique line of inferior maxillary.	Angle of mouth.	Lip directly downward and outward. Gives expression of irony.
Orbicularis oris.[1]	Nasal septum, canine fossa of inferior maxillary, and by accessory fibers from other muscles.	Forms lips and sphincter of the mouth.	Closes the mouth.

[1] The orbicularis oris is not a true sphincter muscle, but consists of numerous layers of muscular fibers having various directions. From these fibers are derived various of the facial muscles, as the buccinator, levator, and depressor anguli oris, the levator labii, zygomatici, and depressor labii.

MUSCLE.	ORIGIN.	INSERTION.	FUNCTION.
Buccinator.	From alveolar process of inferior and superior maxillary bones and pterygo-maxillary ligament.	Orbicularis oris.	Contracts and compresses the cheek; keeps food under pressure of the teeth.
Risorius.	From fascia over the masseter muscle.	Skin at angle of mouth.	Retracts angle of the mouth, as in smiling. Called the "smiling" muscle.
Temporal	Temporal fossa and fascia.	Coronoid process of inferior maxillary.	Raises and retracts the lower jaw.
Masseter.	Zygomatic arch and malar process superior maxillary.	Angle and ramus of jaw.	With the pterygoid, moves the lower jaw forward on the upper; deep fibers the jaw backward.
External pterygoid.	Pterygoid plate and greater wing of the sphenoid.	Neck of condyle of lower jaw.	Chief agent in trituration of the food. Moves the lower jaw forward.

NECK.

Platysma myoides.	Clavicle, acromion process of scapula and fascia.	Inferior maxillary and angle of mouth.	Depresses the jaw. Draws lip and mouth down. Gives expression of melancholy.
Sterno-mastoid.	By two heads, sternum and clavicle.	Mastoid process of temporal bone.	Depresses and rotates the head.
Sterno-hyoid.	Sternum and clavicle.	Hyoid bone.	Depresses larynx and hyoid after they have been drawn up in deglutition.
Sterno-thyroid.	Sternum and cartilage of first rib.	Side of thyroid cartilage.	Depresses the larynx.
Stylo-glossus.	Styloid process of temporal bone.	Side of tongue.	Elevates and retracts the tongue.
Digastric.	Anterior body from inner surface of inferior maxillary; posterior body, groove of mastoid process.	Hyoid bone.	Raises hyoid bone in deglutition; hyoid fixed depresses jaw.
Genio-hyo-glossus.	Superior genial tubercle of inferior maxillary.	Hyoid bone and inferior surface of tongue.	Posterior fibers of tongue forward; anterior fibers of tongue back. Both muscles acting make tongue concave.
Hyo-glossus.	Cornu of hyoid bone.	Side of tongue.	Makes tongue convex.
Stylo-pharyngeus.	Styloid process.	Thyroid cartilage.	Elevates the pharynx.

MUSCLE.	ORIGIN.	INSERTION.	FUNCTION.
Constrictors.	Inf. cricoid and thyroid cart. Mid. cornu of hyoid and stylo-hyoid lig. Sup. inter-pterygoid plate jaw and side of tongue.	Raphè of pharynx.	Lessens the caliber of the pharynx.
Rectus capitis anticus major.	Transverse process and lat. mass of atlas.	Basilar process of occipital bone.	Flexes the head and slightly rotates it.
Scaleni.	Anterior tubercle of first rib. Middle of first rib.	Trans. process of third to sixth cervical vertebræ.	When fixed above elevate first and second rib.

TRUNK.

Trapezius.	Superior curved line of occipital bone, spinal process of last cervical vertebræ, all dorsal vertebræ.	Clavicle, spine of scapula and acromion process.	Elevates the shoulder. as in supporting a weight. Draws head backward.
Latissimus dorsi.	Spines of six lower dorsal vertebræ and lumbar and sacral vertebræ, crest of ileum and three or four lower ribs.	Bicipital groove of humerus.	Aids in giving downward blow, as in chopping; when arm is fixed, aids in raising the ribs; when both arms fixed, draws the whole body forward.
Serrati.	Margin 8 upper ribs. Posterior spine of last 2 dorsal, first 3 lumbar; superior spine of 7th cervical, 2 upper dorsal.	Posterior border of scapula. Four lower ribs. 2d, 3d, 4th, and 5th ribs.	Elevate the ribs. Depress the ribs. Raise the ribs.
Complexus.	Trans. process 7th cervical, 6 upper dorsal, articular process of 3d to 6th cervical.	Occipital bone.	Holds head erect.
Erector spinæ.	Crest of ilium, sacrum, lumbar, 3 lower dorsal spines.	Divides into sacro-lumbalis, longissimus dorsi and spinalis dorsi.	Extension of lumbar spines on pelvis.
Longissimus dorsi.	From erector spinæ.	Transverse process of lumbar and dorsal vertebræ, 7th to 11th ribs.	Erects the spines and bends the trunk backward.
Intercostals, external.[1]	Outer lip of the inferior border of ribs.	Superior border of ribs above.	Raise the ribs in inspiration.
Intercostals, internal.	Inner lip of the inferior border of ribs.	Superior border of ribs below.	Depress the ribs in expiration.

[1] The view given here of the function of the intercostals is that of Hutchinson. This action is, however, disputed by a number of eminent anatomists, as Haller, who thinks they "act in common."

The first theory is the one generally taught in this country, while the theory of Haller has many followers in Europe, and has the support of many observations, both in disease and health.

MUSCLE.	ORIGIN.	INSERTION.	FUNCTION.
Diaphragm.	Tip of sternum, six or seven lower ribs, from behind by two upon aponeurotic notches and bodies of lumbar vertebræ.	Central tendon.	Principal muscle of inspiration. Used also in expulsive acts.
Obliquus externus.	Eight lower ribs.	Median line (linea alba). Crest of ilium, Poupart's ligament.	Compresses the viscera and flexes the thorax. An expiratory muscle.
Obliquus internus.	Lumbar fascia, crest of ilium, Poupart's ligament.	Three lower ribs, linea alba, pubic crest, pectineal line.	Compresses the viscera, flexes the thorax, aids in expiration.
Rectus abdominis.	Crest of pubic bone.	To the cartilages of the 5th and 6th ribs.	Compresses the viscera and flexes the thorax.

UPPER EXTREMITY.

Pectoralis major.	Sternal half of clavicle, sternum, and cartilage, 6th or 7th rib.	External bicipital ridge of humerus.	Depresses the arm when raised by the deltoid. Draws the arm forward.
Pectoralis minor.	Third, fourth, and fifth ribs.	Coracoid process of scapula.	Depresses point of the shoulder.
Deltoid.	Clavicle, acromion, and spine of scapula.	Prominence on the middle of the outer half of shaft of humerus.	Raises the arm directly from the side. Abducts the humerus.
Subscapularis.	External surface of scapula.	Lesser tuberosity of the humerus.	Rotates head of humerus inward and aids, by its tone, in preventing displacement of humerus.
Coraco-brachialis.	Coracoid process of scapula.	To a ridge on middle of inner surface of humerus.	Moves humerus forward and inward.
Biceps flexor cubiti.	Long head, glenoid cavity; short head, coracoid process.	Tuberosity of the radius.	Flexes and supinates forearm.
Brachialis anticus.	Lower half of the shaft of the humerus.	Coronoid process of ulna.	Flexes arm and protects elbow joint.
Triceps extensor cubiti.	Exter. and inter. heads near musculo-spiral groove of shaft of humerus; long head from glenoid cavity.	Olecranon process of ulna.	Extends the forearm. Protects the under part of the shoulder joint.
Pronator quadratus.	Lower fourth of ulna.	Lower fourth of the shaft of radius.	Pronates the hand.
Pronator radii teres.	Internal condyle of humerus and coronoid process of ulna.	Outer side of shaft of radius.	Pronates the hand and aids in flexing forearm.
Flexor carpi ulnaris.	1st head, internal condyle of humerus; 2d head olecranon of radius and from ulna.	Annular ligament, pisiform bone, and 5th metacarpal.	Flexes the wrist.

MUSCLE.	ORIGIN.	INSERTION.	FUNCTION.
Flexor profundus digitorum.	Shaft of ulna.	Last phalanges by four tendons.	Flexes the phalanges.
Flexor sublimis digitorum.	1st head, inner condyle of humerus; 2d head, coronoid process of ulna; 3d head, oblique line of radius.	Second phalanges by four tendons.	Flexes second phalanges.
Flexor longus pollicis.	Shaft of radius.	Last phalanx of thumb.	Flexes last phalanx of thumb.
Palmaris longus.	Internal condyle of humerus.	Annular ligament and palmar fascia.	Tensor of the palmar fascia, and assists in flexing wrist and elbow.
Supinator longus.	External condyloid ridge of the humerus.	Styloid process of radius.	Flexor and supinator of forearm.
Extensor carpi ulnaris.	1st head, external condyle humerus; 2d head, posterior border of ulna.	Base of 5th metacarpal bone.	Extends wrist.
Extensor carpi radialis.	Lower third of external condyloid ridge of humerus.	Base of 3d metacarpal bone.	Extends wrist.
Extensor communis digitorum.	External condyle of humerus.	All of the 2d and 3d phalanges.	Extends the fingers.
Extensor minimi digiti.	External condyle of humerus.	2d and 3d phalanges of little finger.	Extensor of little finger.
Extensor ossis metacarpi pollicis.	Posterior surface of shaft of the ulna and the radius.	Base of metacarpal bone of thumb.	Extends the thumb.
Extensor indicis.	Posterior surface of shaft of ulna.	2d and 3d phalanges of index finger.	Extends index finger.
Interossei, palmar (3).	From the sides of metacarpal bones.	From the aponeurosis of extensor tendons.	Adduct index, ring, and little fingers.
Interossei, dorsal (4).	From the five metacarpal bones.	Sides of the aponeurosis of extensor communis.	Abduct index, middle, and ring fingers.

LOWER EXTREMITY.

Psoas magnus.	Bodies and transverse processes of last dorsal, all lumbar vertebræ.	Lesser trochanter.	Flexes and rotates the thigh outward; flexes trunk on pelvis. Assists in keeping erect position by supporting spine and pelvis on femur.
Iliacus.	Iliac fossa, crest, base of the sacrum.	Lesser trochanter, oblique line of femur to linea aspera.	Acting with psoas magnus, flexes thigh and rotates femur outward.
Tensor vaginæ femoris.	Outer lip of crest of ilium; anterior superior spinous process of ilium.	Fascia lata, outer side of thigh.	Tensor of fascia lata, also abducts and rotates thigh inward.

MUSCLE.	ORIGIN.	INSERTION.	FUNCTION.
Sartorius.[1]	Anterior superior process of ilium and upper half of notch below.	Upper internal surface of shaft of the tibia by U-shaped aponeurosis.	Flexes the leg on the thigh, and its continued action flexes thigh, the pelvis; next rotates thigh outward.
Quadriceps extensor.[2]	Vastus, external, anterior border of greater trochanter and linea aspera; vastus, internal, lip of linea aspera. Rectus femoris anterior inferior spine of ilium, edge of acetabulum.	Tuberosity of tibia border of patella. Common tendon contains the patella.	Extends leg upon thigh. Rectus assists psoas and iliacus in supporting pelvis and trunk upon the femur or in bending it forward.
Pectineus.	Ilio-pectineal line of innominata and pubes; fascia of anterior surface of muscle.	Femur below lesser trochanter.	Adducts thigh; flexes thigh and rotates it outward.
Adductor magnus.	Descending ramus of os pubis and ascending ramus and tuberosity of ischium.	Linea aspera of femur.	Adducts the thigh and rotates it outward.
Adductor longus.	Front of os pubis.	Linea aspera, middle part.	Adducts and flexes the thigh.
Gracilis.	Symphasis and ramus of os pubis.	Upper part to inner surface of shaft and lower part to inner tuberosity of tibia.	With sartorius flexes the leg and rotates it inward. It also adducts the thigh.
Gluteus maximus.	Gluteal line and crest of ilium, sacrum, and coccyx.	Greater trochanter and fascia lata and linea aspera of femur.	Keeps trunk in erect position. Extends and rotates thigh outward. Enables the body to regain erect position after stooping.
Biceps[3] (*flexor cruris*). Acts with Semitendinosus and Semimembrinosus.	Long head from tuberosity of ischium; short head from linea aspera, outer lip.	Head of fibula and external tuberosity of tibia.	Flexes the leg on the thigh and rotates the leg outward.
Tibialis anticus.	Outer tuberosity, upper part of shaft of tibia.	Internal cuneiform bone and metatarsal bone of great toe.	Flexes tarsus upon leg.
Extensor longus digitorum.	Outer tuberosity of tibia and upper part of shaft of fibula.	Second and third phalanges of toes.	Extends the toes.
Extensor proprius hallucis.	From interosseous membrane and middle part, anterior surface of fibula.	Last phalanx of great toe.	Extends the great toe.

1 The sartorius does not adduct the leg, as was formerly supposed, so that the name "tailor muscle" is inappropriate.

2 This is the great extensor muscle of the leg, and divides into four portions, named respectively, *rectus femoris*, *vastus externus*, *vastus internus*, and the *crureus*.

3 The biceps, semitendinosus, and semimembrinosus are called the "hamstring muscles." The hamstring tendon is composed of the tendons of the three muscles just mentioned with that of the gracilis.

MUSCLE.	ORIGIN.	INSERTION.	FUNCTION.
Gastrocnemius.	Inner head from inner condyle and outer head from external condyle of femur.	Tendo Achillis.	Extends the foot. Used in standing, leaping, and walking.
Soleus.	Back part of head of fibula, oblique line, and internal line of tibia.	Os calcis by tendo Achillis.	Extends the foot.
Plantaris.	Linea aspera and ligament of knee joint.	Os calcis by tendo Achillis.	Accessory to gastrocnemius.
Popliteus.	External condyle of femur, posterior ligament of knee joint.	Shaft of tibia.	Aids in flexing leg on thigh. Leg flexed, rotates leg inward.
Interossei, dorsal.	Adjacent surface of metatarsal bones.	Base of first phalanges.	Abduct from the middle of the second toe.
Interossei, plantar.	Inner lower surface of three outer metatarsal bones.	Base of first phalanges of three outer toes.	Adducts the outer three toes.

Motion, however, is needed in other parts as well as in the skeleton, for respiration, circulation, digestion, and other functions. Muscular tissue is therefore found in the larynx, the trachea, the bronchial tubes and their branches, the tongue, the alimentary canal, the arteries, the veins, the heart, and in some other parts of the body.

Skeletal Muscles.— The typical skeletal muscle is more or less fusiform in shape, and consists of an expanded fleshy portion, the *body* (Fig. 48), and a flat or narrow portion (*tendons*) composed of white inelastic tissue, by which it is attached to the bone or to other muscles. If we should examine the body, however, we would find the muscles differing very much in shape and size. Some of the more important forms are shown in Fig. 34. When a muscle has the tendons at the side, and the fibers arranged along it, like the vane of a feather, it is called *penniform;* when the fibers are on both sides of the tendon, *bipenniform;* with the tendon at the end, the fibers radiate — are *fan-shaped;* consisting of an expanded portion, and ending in a tendon above and below, *fusiform,* or *spindle-shaped;* when it originates from two tendons, a *biceps;* when from three tendons, a *triceps;* consisting of two bodies with an intervening tendon, *digastric;* made up of circular fibers, so as to form a muscular ring, *sphincter.*

From the specimen you have for dissection, see how many of these forms you can select.

Arrangement of Muscles.— From the dissection of a rabbit we may learn that the muscles are arranged into two or more well-marked layers, bound together by a common sheath (*fascia*) of connective tissue. Those near the surface are known as superficial muscles; those near the bone as deep-seated muscles.

Number of Muscles.— There are more than five hundred muscles in the human body, each of which has its respective name and function, and by the separate or combined action of these the various movements of the body are produced.

We cannot, in our brief study of the subject, learn the names and action of all these muscles, but a study of them in connection with Figs. 35 to 47, Plates II to VI, and the diagram of the principal muscles, will help us in understanding the use of some of the more important muscles of the body.

The movements of our body differ very much in the number of muscles they call into action; to illustrate, try Experiment 23.

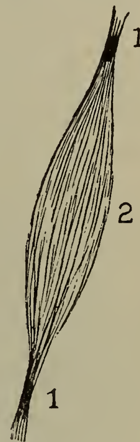


FIG. 48.—TYPICAL MUSCLE. 1. Tendon. 2. Body.

Structure of Muscles.— Let us now examine more thoroughly some of the muscles. Let us take the biceps muscle of the arm. We have noticed that a muscle generally consists of two parts,— the fleshy portion, or the contractile part, and the tendon, or the inelastic part. The tendons are composed of white, inelastic fibrous tissue, and are generally very strong. This gives the muscles a firm attachment, so that the entire contraction will be effective in producing motion. What difference would there be if the tendons were elastic?

The tendons are attached to the coverings of the bones (*periosteum*) directly or indirectly by means of other tendons which are attached to the periosteum. The tendons are most

numerous near the large joints, where they permit free motion, and yet occupy little space.

What inconvenience would there be in having the larger muscles cover the joints?

Grasp your arm near the elbow, and bend it forcibly, and you can feel the tense tendon of the biceps as it is drawn by the muscle to move the forearm. The tendons may be easily noticed in the back of the hand. The wonderful dexterity and flexibility of the hand is due for the greater part to the numerous tendons of the palm and back of the hand, and to the fact that the muscles which move them are located in the arm. The strongest and largest tendon of the body connects the larger muscles of the calf of the leg to the heel bone (*os calcis*). It is called the *tendon of Achilles.*

From what we have seen, we learn that when the muscle contracts, it pulls on the tendons, which transfer the motion to the bones to which they are attached.

From our dissection we have learned that tendons are variously situated at each end of the muscle, as in the muscle which bends the arm,— in the middle of the muscle, its fibers running obliquely from it, looking like the quill of a feather; or they may spread out into membranes, as in the tendons of the *occipito frontalis,* when they are known as an *aponeurosis;* or they may have a tendon in the middle, as well as at each end, as in the digastric muscle of the jaw.

There are numerous places in the body where muscles have to glide over prominences or pass through grooves; if there were not such special provision, their movement over these parts would cause undue friction and heat. This is prevented by these parts having a special membrane, which covers or lines the part, secreting a fluid that renders the movement easy. These membranes are called *synovial membranes.*

The tendon attached to the part that is fixed is called the *origin;* the one attached to the part that moves, the *insertion.* Determine and examine the origin of some of the more important muscles mentioned in the list. To what part of a machine does the tendon correspond?

Gross Structure of the Muscle.— Let us return to the study of the body of a muscle. Observe that it is covered by a sheath of connective tissue (*epimysium*) (Fig. 13). On examination of a transverse section of the muscle we find that it is not a solid piece of muscular substance, but made up of a great many parts, some of which are almost microscopic in size, and they are separated from each other by partitions of connective tissue (*perimysium*). From dissecting out some of the smaller bundles, and examining them with the microscope, we find that they are made up of smaller bundles, and that the smaller bundles

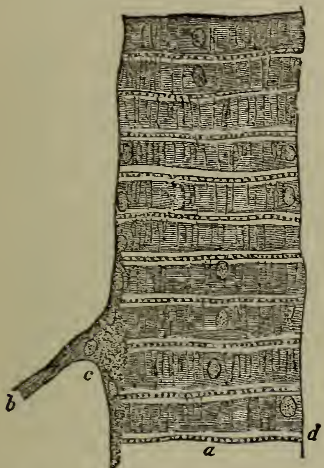


FIG. 49. A.—MUSCULAR FIBER FROM BEETLE (Hydrophilus piceus). *a.* Substance of muscle. *d.* Cross striæ. *c.* Doyere's prominence. *b.* Entering of nerve fiber. (Sanderson).

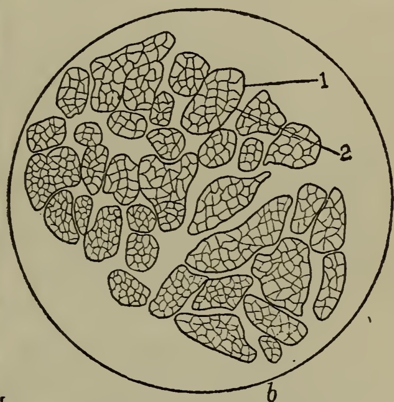


FIG. 49. B.—TRANSVERSE SECTION OF MUSCLE FIBER FROM TONGUE OF CAT. 1. Muscle fiber. 2. "Cohnheim's areas." (Brinckley. C. W. B.)

(*fasciculi*) have a delicate sheath (*endomysium*), and that they are made up of delicate thread-like bodies (*muscle fibers*).

Microscopic Structure of Muscles.— *Skeletal Muscles.*— Let us now examine the individual muscular fiber (Fig. 14), for it is the difference in their structure that gives to the three classes of muscles their respective properties. The skeletal-muscle fiber is on the average one five-hundredth of an inch in diameter, and a little over an inch in length. It is cylindrical in form, and presents numerous transverse mark-

ings. Each fiber has a transparent, elastic sheath called the *sarcolemma.*

We have learned from our experiment that muscles are often arranged in pairs. The muscles which act in opposition to each other, as the biceps and triceps of the arm, are called *antagonists.*

Were it not for such muscles our movements would be slow, and in many cases impossible. Suppose there were only muscles to bend the limbs, can you think of any inconvenience that would arise? Try the experiment. What do you learn?

Names of Movements.— Perform the following movements, and notice what muscles are brought into action: Bend (*flex*) the arm, straighten out (*extend*) the arm; draw the arm away (*abduct*) from the body; bring it to (*adduct*) the body; turn the hand (*pronate*) so that the palm will be down; turn the hand (*supinate*) so as to have the palm up. Do you find different muscles for each of these movements?

Kinds of Muscles as to Function.— Muscles which bend the limbs are called *flexors;* those which straighten the limbs, *extensors;* those which draw parts away from the body, *abductors;* to the body, *adductors;* those which lift parts, as the eyelid or corner of the mouth, *levators*; that draw parts down, *depressors;* those that turn the palm of the hand up, *supinators;* the palm down, *pronators.*

How Muscles Are Named.— Muscles are named in various ways: from their form, *trapezius;* their position, *latissimus dorsi;* their size, *serratus magnus;* their origin, *biceps flexori cubiti;* or their function, *levator anguli oris.* (See Glossary.)

The muscle fiber is composed of contractile protoplasm. Under very high power its structure is seen to be very complex, more complex than we can here consider; but it is necessary that we study some of its more important features.

The contractile substance is marked by alternate dim and light stripes (Fig. 49) running across the fiber, which has given to them the name of striped, or striated, muscles.[1]

[1] If a transverse section of a muscle fiber is examined under high power, it is seen to be subdivided into smaller areas (Fig. 49) (the *areas* of *Cohnheim*), which

Plain Muscular Tissue.— Involuntary, or plain, muscular tissue is composed of spindle-shaped cells (Fig. 15) about one five-hundredth of an inch in length and about one eighth as wide. It has one or more prominent nuclei, which are oval, and exhibit intranuclear network, and one or more nucleoli.

The cell substance presents a longitudinal, but no transverse, striation, and each cell seems to have a delicate sheath. The cells have between them a small quantity of cementing substance. These are collected together in bundles covered by connective tissue. Along this connective tissue the blood vessels pass, and from these capillaries go to the individual fibers. (Where found, see below.)

Heart Muscle.—While the heart is an involuntary muscle, it is quite different from the plain involuntary muscle tissue. Its fibers, like those of the skeletal muscle, present transverse marks (Fig. 16), or striæ. Its fibers, however, are smaller than those of the skeletal muscles, and are made up of oblong-shaped cells having a prominent nucleus near its center, and with one or more nuclei, and whose cells sometimes give off branches to other cells. The cells are without an investing sheath. These cells have an abundant supply of blood vessels and lymphatics.

Distribution of Plain Muscle Tissue. — This tissue is found in the alimentary canal below the middle of the esophagus; in the trachea and bronchi; in the air cells in the middle coat of the arteries, and in some veins; in the larger lymphatics; in the bladder and ureters; in the ducts of glands in the iris and ciliary muscles, and in the true skin, especially between the bases of the papillæ.

represent the muscle columns of which the fiber is composed. After death, or on being hardened in alcohol, chromic acid, and certain other reagents, it presents a well-defined longitudinal marking, and may be easily split up into smaller threads, or fibrillæ, which correspond to the muscle columns (*sarcostyles*) of the living muscle. By treating the muscles with certain reagents, they may be split up into transverse disks. From this we learn that the fibers are composed of a mass of fibrils (*sarcostyles*) imbedded in interfibrillar substance (*sarcoplasm*), and composed of alternate segments of dim and clear substance. It is these muscle columns which are the actual contractile elements of the muscle. Just beneath the sarcolemma will be seen numerous dots, or nuclei, which under high power appear nucleated and imbedded, or surrounded by a variable amount of protoplasm. A nucleus with its surrounding protoplasm is called a *muscle corpuscle.*

Blood Vessels of Muscular Tissue.— On account of the large amount of work the muscles have to do, they need an abundant supply of blood, not only to furnish material to supply the constant exercise of energy, but to carry away the waste products of their action as well.

When we study their structure, we see how admirably this demand has been met. Not only does the connective tissue bind the various parts of the muscle together, giving it support, but it also serves as the means by which the blood vessels and nerves are distributed to the various parts of the muscle.

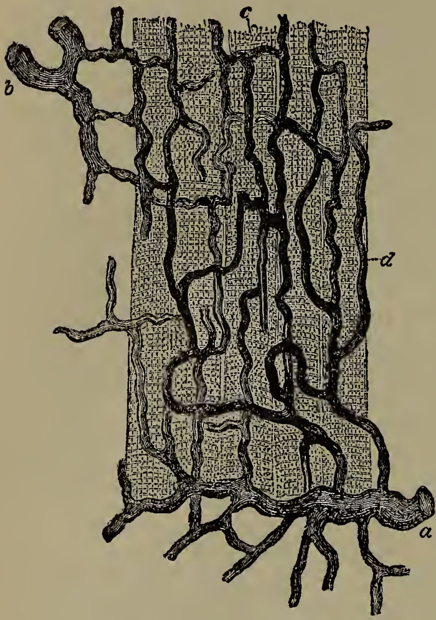


FIG. 50.—SECTION OF AN INJECTED MUSCLE OF A RAT.

a. Arteriole. *b.* Vein. *d.* Capillaries between them. (After Sanderson.)

The arteries, accompanied by the veins, enter at various points, branch into the connective tissue (*areolar*) between the fasciculi, and finally terminate in capillaries that form an oblong network (Fig. 50) around the fibers outside of the sarcolemma. These capillaries are very small, and from them exudes the fluid by which the muscle fiber is nourished.

It is also in the connective tissue that the lymph spaces, that make the beginning of lymphatic vessels, are formed, so that each fiber is surrounded by a capillary blood vessel and a lymph space, the lymph acting as a medium of exchange between the blood and the muscle tissue in a way that will be explained when we study the lymph.

Nerves of Muscle Tissue.— It is from the nerves that the muscle receives its normal stimulus; it is essential that it be well supplied with them. This we find to be the case. The nerve fibers, chiefly medullated, are from the central nervous system. The nerves branch in the connective tissue, first forming plexuses, and then divide until a single nerve fiber enters each muscular fiber, the primitive sheath of the nerve fiber fusing with the sarcolemma; while the axis cylinder of the nerve passes through it, and ends in a terminal ramification called an *end plate,* on the substance of the fiber (Fig. 51). Each fiber appears to receive one end plate about its middle, and so distributed that a nervous impulse along the different fibers going to the muscle reaches the different parts about the same time, and thus produces a simultaneous contraction in the organ.

Involuntary muscles are supplied with nonmedullated nerve fibers derived from the sympathetic system. In some cases they end in knot-like processes.

Muscular Contraction.— One of the most characteristic properties of living animals is the power to produce spontaneous movement. It may be simple, as the protruding or flowing out of the body substances, and exercised by any part of the body, as in the movement of the amœba, or it may be more complex and restricted to a particular part or tissue of the animal. In the higher animals the power of producing motion by contraction is restricted to a single tissue, the muscular tissue.

By experiment with a muscle-nerve preparation (Fig. 33), we may learn of the mode and nature of muscular contraction.

By stretching the muscle it is found to be elastic, while slight, yet it is perfect in returning to its exact length when the force is removed.

By the application of the electric current a muscle may be made to contract, or shorten. Similar effects may be produced by heat, certain chemicals, or by a blow upon it. Those agents which cause the muscle to contract are called

stimuli, and the property of responding to stimuli is called *irritability.* The stimulus may be applied to the nerve going to the muscle or to the muscular tissue direct. The muscles, when at rest, are normally slightly contracted, keeping them on a slight tension, ready to contract with the least expenditure of force. This normal tension, or *muscular tone,* is due to the influence derived from the central nervous system; for if we cut the nerve going to the muscle, it at once loses its tone, and becomes larger and relaxed.

The muscular fibers have the power of contraction independent of the nervous system. This is shown by use of curare, which paralyzes the motor nerves, but does not affect the muscular tissue. A muscle thus prepared responds to direct stimulation. Similar results may be attained by the use of ammonia, which destroys the nerve, and yet stimulates the muscular tissue.

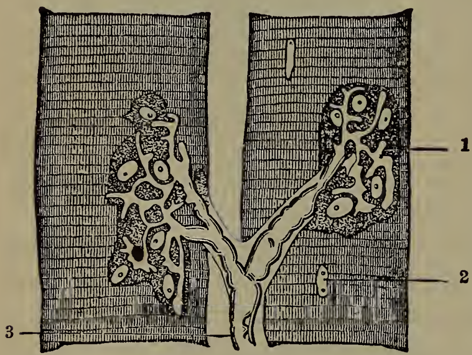


Fig. 51 — Muscle Fiber with Motorial End Plates.
1. End plate. 2. Muscle nucleus. 3. Nerve.

We may study the phenomena of contraction by means of the muscle curve produced by a myograph (Fig. 52). The muscle is so arranged that its contraction moves a lever, the end of which comes in contact with a cylinder covered with smoked paper, and revolving at a fixed rate so as to receive a tracing of the motion of the lever.

A muscle curve is represented in Fig. 52. From the study of the muscle curve produced by a single contraction we learn that it consists of three phases: —

1. A latent period, during which the lever does not change from the horizontal line, and in which no apparent change is

taking place. This phase is probably caused by propagation of the impulse along the nerve, and by the preparatory changes in the muscle. In the fresh muscle it occupies about one one-hundredth, or more correctly, probably, one four-hundredth, of a second. As the muscle becomes fatigued, this period becomes longer.

2. That of contraction, causing rising of the lever. The height to which the lever rises becomes less as the muscle tires, but the duration of the phase remains the same. This phase occupies four one-hundredths of a second.

3. That of relaxation, in which the muscle returns to its former condition, causing the descent of the lever. It occupies five one-hundredths of a second, but becomes longer as the muscle tires.

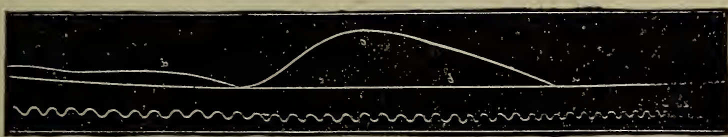


FIG. 52. — NORMAL MUSCLE CURVE.

Curve from a frog's gastrocnemius traced on a pendulum myograph. Time tracing of 120 double vibrations per second. Stimulus applied at *a*. *a b* (1) Latent period. *b c* (2) Contraction. *c d* (3) Relaxation. *e* (4) Slower relaxation. *c*. Height of contraction. Wavy line, time markings. (After Rutheford.)

A single muscular contraction, or twitch, is thus completed in about one tenth of a second, but its time will vary with the condition of the muscle, being much longer when the muscle becomes fatigued.

By sending a second shock before relaxation begins, a second curve is produced, and added to the first (Fig. 53); and on increasing the shock, succeeding shocks will start from some part of the preceding one, causing the curve to rise to a greater height, and end with a more sudden relaxation. The shocks may be increased until the interval between them will not be noted, the curve being a general rise. Such a state of continued contraction is called a *tetanus*. Every contraction of a voluntary muscle in the living body is considered to be tetanic in nature, a sudden jerk being in reality

a tetanic contraction of short duration; i. e., it is produced by a number of quickly repeated stimuli. A fine illustration of a tetanus is seen in a person holding the handle of a strong magnetic induction machine when a current is passing. The hands become cramped, and the fingers bent so that one cannot let go of the handles.

A fatigued or exhausted muscle cannot act, owing to the accumulation of the waste products from its own action. If

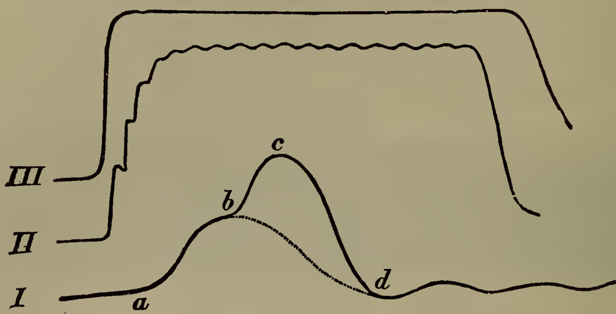


FIG. 53.—EFFECT OF REPEATED STIMULI.

I. Two successive shocks. II. Successive contraction produced by 12 inductions per second. III. Curve produced by very rapid induction shocks (complete *tetanus*).

permitted to rest, it may recover by the circulation bringing fresh material and removing the waste products.

Tetanus may be produced by some poisons, as strychnine, or by some disease, as lockjaw.

The chemical changes which take place in a muscular contraction are very complex, and their exact nature is not fully known; but we have some facts which will aid in forming an idea of their probable nature.

The muscle cell, by its own activity, makes from the material furnished by the blood, or from a part of its own substance (*protoplasm*), material in the form of potential energy, which is capable of being set free by the stimulus of the nerve force. This brings about a series of physical, chemical, and electrical changes, setting free energy that brings about the contraction and the resulting motion. Carefully note that the cell does not die, but rather by its activity

it effects a series of changes which produce the motion, leaving it ready to repeat over and over these changes, each time becoming reloaded for another change. The need of food to a muscle is not so much to furnish material for a new cell as to give it something from which it may make something, by the discharge of which by the nerve impulse it can produce energy for contraction.

We may briefly sum up the changes which take place during muscular contraction, viz.: —

I. *Structural.*

1. The whole muscle shortens, thickens, and hardens.

2. The blood supply (arterial) is increased, while the venous blood and lymph is forced out.

3. The sarcostyles of the fibers contract, the dark bands encroaching on the clear areas.

II. *Physical.*

1. There is a slight rise in temperature; the venous blood from the active muscle being of a higher degree of temperature than from a muscle at rest.

2. A change in electric condition; a negative variation of the natural muscle current is produced.

3. Increase of the extensibility of the muscle; a given weight stretches a contracted muscle more than it would the same muscle at rest.

III. *Chemical.*

1. The chemical changes taking place in a muscle are increased during its contraction.

2. There is a sudden increase in the amount of carbon dioxide (CO_2), and the amount of oxygen (O) absorbed is increased, but not in proportion to the amount of CO_2 given off.

3. Sarcolactic acid ($C_3H_6O_3$) is produced, and the muscle becomes acid in its reaction.

4. Kreatin ($C_4H_9N_3O_2$) is formed by the muscle at rest, but not by the contracting muscle. There is probably no nitrogenous waste during contraction.

5. The formation of sugar ($C_6H_{12}O_6$), probably from the change which takes place in the glycogen ($C_6H_{10}O_5$).

Chemical Composition of Muscles. — As we have seen, there is a marked difference in the composition of the muscle

at rest and during contraction. Even when at rest, the muscle is engaged in active chemical change; carbon dioxide is given off, and kreatin and other products are found. While it is difficult to determine the exact composition of living muscle, yet we get many valuable facts from the study of the dead muscle (*rigor mortis*). It presents the following contrasts:—

1. Living muscle is quite translucent; dead muscle, opaque.
2. Living muscle is very elastic; dead muscle, less elastic.
3. Living muscle is irritable; dead muscle gives no response to stimulus.
4. Living muscle contains myosinogen and a ferment; dead muscle, myosin, which seems to be coagulated myosinogen.
5. Living muscle at rest is alkaline; dead muscle, acid at first, but alkaline when putrefaction sets in.
6. Living muscle contains muscle-plasm; dead muscle, muscle clot (*myosin*) and muscle serum.[1]

Muscular Sense.— There seems to exist in the muscles a sense by which we are enabled to judge of the activity and degree of contraction of the muscles. By an examination of our experiences in various movements of the body we learn that we are conscious of the position of any part of the body, even with the eyes closed, and during the movement of the limbs we estimate the character and force of the muscular movement. But it is difficult for us to analyze our experiences, and to say which are due to muscle and which to the other sense, as they are all intimately related; and muscular sensations are closely connected with cutaneous and other sensations, and to such a degree that some scientists doubt the existence of the muscular sense, independently of the skin. But this belief is not well founded, as cutaneous sensation may be lost or greatly impaired, while the power of

[1] In addition to the products mentioned above, there are pepsin, fibrin ferments, starch (*amylolytic*) ferments, muscle pigment (*myohematin*), sarcolactic acid, acetic and formic acid, carbohydrates, glycogen, glucose (or maltose) and inosite.

The principal nitrogenous crystalline bodies are xanthin, hypoxanthin, carnin, taurin, urea, and in normal condition a very small amount of uric acid. The chief salt of the muscle is potassium phosphate.

co-ordination remains; and in the disease of the spinal cord called locomotor ataxia, in which the power to use the muscles with the proper degree of force is lost, the tactile temperature and pain sensation may be unimpaired. From the microscopic study of the muscle we learn that the muscle is not only supplied with fibers ending in the motorial end-plates, but also with different fibers, some of which are described as ending in fine fibrils among the muscular fibers; and they probably serve for the afferent impulses of the muscular sense. The sense of fatigue is probably produced by a condition of the muscles. In addition to the impression received from the muscle itself, it is thought by some that tendons and ligaments may supply impulses which enter into the muscular sense and thought to be given by the peculiar nerve endings found in tendons, called the *organ of Golgi.*

The muscular sense is very important, and, in connection with the other senses, contributes much to our knowledge of the external world. While muscle fibers are difficult to localize, they are delicate, and enable us to arrange and force muscular contraction. This sense not only aids us in the acquiring of knowledge, but it makes possible the almost magic touch of the artist and other skillful manipulations. It is an important factor in our learning of space relations between things generally: but as to how the muscles help in these processes, whether by their own sensation or by awakening sensations of motion in the skin, retina, and articular surfaces, has not been determined. It is in combination with these that other senses bear their most important part. In all the senses the muscles are more or less connected. In taste, the movement of the tongue is important; in smell, the air carries the particles into the nose; in hearing, the muscles of the tympanum contract (or those of the head) to more indirect sound. But it is in sight and touch that the muscles become of greatest importance. The most mobile parts of the body have the sense of touch best developed. By combination of muscular and tactile sensation, we are enabled to estimate small differences of weight and resistance, and thus

appreciate surface; and this sense, with vision, enables us to form an idea of perspective, or solidity and form.

Kinds of Physical Exercise.— The value of any physical exercise depends much upon its nature, the number and kinds of muscles it calls into action, and the effect it has upon the body in general.

According to the quantity of work represented by an exercise, it is said to be *gentle, moderate,* or *violent.* When the quantity demanded is small, as in walking slowly, the exercise is called gentle; when more work is done, as in walking briskly, it is called moderate; when large in quantity, as in running, it is said to be violent.

But quantity alone cannot be taken as a standard by which to measure the value of an exercise; for although the quantity of work done in two cases may be the same, yet the effect of the exercise on the system may be quite different, from the number and relation of the muscles brought into action, and the different conditions under which it places the other organs of the body.

There should be a clear distinction made between difficulty of work and quantity of work; if not, we shall make serious mistakes in choosing exercises for health. Many of the so-called violent exercises and exercises of strength are only exercises of skill, and in many difficult exercises we really do the same amount of work that we do in others which seem to be easy; e. g., a little girl will skip one hundred times in a minute, jumping six inches high, but how much more difficult for her to raise herself fifty feet high in one minute by means of rings placed six inches apart; and yet the work done in each case is the same. What makes the latter more difficult is that the body has to be raised by the smaller and weaker muscles of the arms, while in skipping, the work is done by the strong muscles of the lower limbs.

Exercises of Strength.—Exercises of strength are those in which each movement represents a great quantity of work, and calls into action the contractile power of a great number of muscles, as carrying a heavy burden.

In exercises of strength, will, as well as muscle, is necessary. Other things being equal, the man with stronger will produces the more muscular energy, as his muscles will contract more vigorously under the stimulus of a strong will. In exercises of great strength, the whole body is put into a state of rigidity, that the various parts may act either for support or leverage, the breath is held, and the veins of the thorax are compressed; the elimination of carbon dioxide is thus hindered at the time when it is being most rapidly generated. They further lead to the compression of the great arteries, the veins, and the heart, producing a profound disturbance in the pulmonary circulation just at the time when pure blood is most needed, so that in protracted efforts the person has to stop for breath before the muscles are fatigued. It will be seen that such exercise is not the kind suitable to a student or the person of sedentary habits, whose circulation is already sluggish, and whose nerves are more or less exhausted. *An exercise which makes a drain of will power is not suited to those who are mentally fatigued.*

Exercises of strength demand greater muscular expenditure, but they produce all the conditions necessary for energetic tissue repair. They demand very little co-ordination, and do not demand frequent repetition of movement. They make a less disturbance of the nerves than exercise of speed, and do not make the drain on the brain, like exercise of skill. This form of exercise is favorable to all nutritive functions, increasing the activity of all the organs of the body, while leaving in relative repose the nerve centers and psychical faculties. Such exercises tend to increase the weight of the body.

Exercises of Speed.— Exercises of speed are those in which there is very frequent repetition of muscular movement. The various exercises of speed differ very much as regards the intensity of work. Running is a violent exercise, while in piano playing, although the fingers are moved with extreme speed, there is a very slight expenditure of energy.

In considering exercise of speed, two things are to be noticed: 1, the rapidity with which work accumulates; 2, the speed with which movements succeed each other.

The rapidity with which work accumulates depends upon (1) the quantity of work represented by each muscular effort, and (2) the number of these efforts in a given unit of time. A person going slowly upstairs with a heavy burden, and a person running as fast as he can along a level road, are both doing a great quantity of work in a short time; one by very slow movement, the other by very rapid movements. In each case work accumulates. The formation of carbon dioxide is in proportion to the sum total of energy expended in a given time. The thirst for air is closely related to the carbon dioxide produced. This thirst for air is produced by intense muscular work, be it from speed or strength. In running at simple play, one absorbs, without making any painful muscular effort, a greater quantity of oxygen than one who has been made to use heavy dumb-bells, although the amount of work done may be the same. In exercises of speed, the greater exhaustion is of the nervous energy. It has a marked effect on nutrition, as shown by men accustomed to exercises of strength; as porters, who are usually of a massive build, become more so as they practice their occupation, while those engaged in exercises of speed, as runners and fencers, are generally of slender build.

Exercises of Endurance. — In exercises of endurance the work is continued for a long time. The expenditure of force is determined less by the intensity and rapidity of successive efforts than by their duration.

In an exercise of strength, work accumulates, as each muscular effort is very intense. In an exercise of speed, work multiplies; for while the movements have little energy, they come in such rapid succession that the small intensity leads in the end to accumulation of work. In exercise of endurance, the muscular efforts following the period of rest after sufficient interval, the work is fractional, the quantity of work not exceeding its power of resistance. An exercise of endurance may become an exercise of speed, if the efforts

follow in rapid succession; or one of strength, if the effort is greater than the power of resistance; i. e., is beyond the strength of the individual.

To the man learning it, rowing seems to be an exercise of strength; for the waterman, it is only one of endurance, he being able to row all day without unusual fatigue. The great difference we notice in persons as respects their power to endure continued work, is due largely to their different respiratory powers.

In order that an exercise may be long continued, it must not lead to breathlessness. "We can go on walking in spite of weary limbs and sore feet, but we cannot go on running when we are out of breath."

The physiological effect of exercise of endurance is to spare the organs, while increasing, in a salutary degree, the play of their functions. One of its most marked features is that it gives the organ power of repairing, even while doing the work. Thus the carbon dioxide is removed from the system as fast as formed, and there is also a considerable increase in the amount of oxygen.

While exercises of endurance have the advantages mentioned, there is one very important disadvantage; i. e., while they render more active the interchange of gases, and enrich the blood with a greater quantity of oxygen, they do not call into action the entire capacity of the lung, thus causing every air cell to become inflated and active, and bringing about a healthier action and a fuller development of the lungs.

Exercises of endurance (1) allow the performance of work with great economy of fatigue; (2) they give the system the benefit of a supplementary acquisition of oxygen without exposing it to the dangers of forced respiration.

Time for Exercise. — The time for exercise is important, and must be largely determined by the habits and condition of the individual. If the person is strong, exercise on rising in the morning, and before breakfast, may be engaged in with good results to the person; but persons enfeebled by poor health or age should not engage in such exercises, or if at all, only in very gentle exercise.

It is a very safe rule never to engage in vigorous exercise just before or after a meal. As we have seen, a large blood supply is needed for vigorous exercise. If this demand is made during the time of the digestion of a meal, the organs are deprived of their proper food supply, and thus interfere with the process of digestion.

We should not engage in vigorous exercise when fatigued from mental or nervous strain, as nerve force is needed in muscular effort as well as in mental activity. If the exercise is moderate, however, it may be of benefit.

The Place of Exercise.— If possible this should be in the open air and in the sunshine. If this cannot be done, the room in which the exercise is taken should be well ventilated and well lighted.

The Amount of Exercise.— The amount and kind of exercise must be governed by the age and physical condition of the person. Very vigorous persons may engage in exercises of strength; the young, in those of speed; the feeble and aged, in those of endurance, the intensity varying according to the strength of the individual. The young should not be called upon to do heavy tasks, as they have upon them the extra demands of growth; and if the exercise is carried to extremes, it will interfere with their development. The exercise should never be carried to the point of extreme fatigue. If our resting fails to rest us, or restore our vigor, or if it fails to give us strength, it should be a warning to us that we are overworking ourselves; we should at once lessen the amount or degree of the exercise.

Regularity of the Exercise.— It is very important that the amount and time of the exercise should be regular. *Strength is not gained by spasmodic efforts.* It is the regular, persistent exercise that gives strength and tone to the muscles and vigor to the body.

Variety of Exercise.— The exercise should be varied, so as to call into action as many muscles as possible. Probably there is no one exercise that will do this, so we should vary our exercises. A careful study of the muscles called into

action by the various exercises will enable us to choose those best adapted to our purpose. We should consult some good work on physical training whose province it is to discuss this question, rather than that of an elementary physiology.

Manner. — The exercise should not be violent, such as would lead to a quick exhaustion. The change from rest to motion, and the change from motion to rest, should be gradual. When too sudden, it brings too great a strain upon the vital organs, especially the heart, which, it must be remembered, is a very delicate organ.

Effects of Alcohol on the Muscles.— We can trace the effects of alcohol on an organ to one or all of three sources: (1) the nerves, (2) the blood vessels, (3) metabolism of the cells. As we have seen, the muscles are classed with the master tissues of the body, and injury to them therefore means serious injury to the entire organism.

The injury to the muscles through the nerves by the habitual use of alcoholic drink is shown as follows: —

1. Loss of muscular control, as seen in the person when intoxicated. While this is temporary, its constant repetition will result in serious injury to the muscular control and coordination. Such muscles will lack power and accuracy in their contraction, thus destroying the skill and power of the person possessing them.
2. Through the overstimulation they are forced to overwork, and thus are exhausted, which is especially true of the heart.
3. By the stimulation of the vaso-dilator nerves by the dilation of the blood vessels, which brings to the muscles an undue blood supply. While blood is needed, too large a proportion is injurious.
4. Alcohol affects the chemical changes (*metabolism*) which take place in the cell, causing them to change the protoplasm into fat producing (*"fatty degeneration"*), which takes away from the muscle its contractibility. This frequently takes place in the muscles of the heart.

The laborer, the mechanic, and the artist, whose best capital is their muscular touch and skill, are robbing themselves when they take alcohol as a beverage, because it will take from them their skill, destroy their usefulness, and rob them of their means of support.

CHAPTER V.

THE NERVOUS SYSTEM.

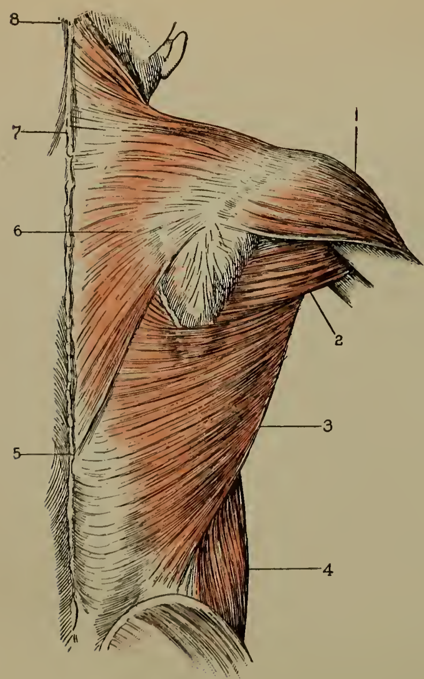
EXPERIMENTS AND DEMONSTRATION.

I. Dissection of the Brain.—Remove the bone from the upper part of the skull so as to expose the brain. This may be easily done by means of the bone forceps if care is taken not to injure the brain substance by pressure. Carefully cut away the investing membrane (*dura mater*), and handle the brain carefully, so as to avoid tearing the nerve roots. Notice at what points the more important branches are given off from the brain, and where they enter the skull. Notice that the cavity in which the brain is found is continuous with that of the vertebral column. Clip off the lower portion of the brain where it passes into the spinal canal. The large opening through which it passes is called the *foramen magnum* (Fig. 90). Notice carefully how the brain rests in the skull. In removing it, care should be taken not to cut the large arteries.

It is best to wash out the blood vessels by injecting them with a salt solution, afterward filling them with a ninety-per-cent solution of strong spirits and then tying them. The brain should then be placed in a solution consisting of sixty parts of ninety-five-per-cent alcohol and forty parts of two-per-cent formalin. It is best to have four or five times as much of the solution by volume as there is of the brain. It is generally best to put it into a weak (fifty per cent) solution of spirits, and then remove it to the stronger solution, in which it should remain for a month or more to harden it thoroughly.

Under the subject of circulation is given directions for injecting the brain.

1. Notice (*a*) the large front mass (*cerebrum*), and make a careful note of its surface markings; (*b*) the por-



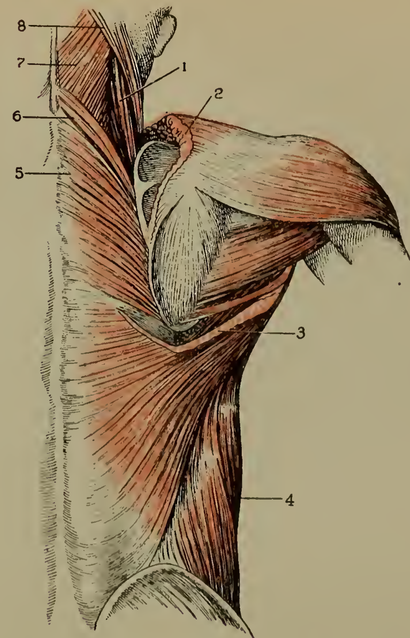


PLATE III

FIG. 39.—MUSCLES OF BACK.

1. Deltoid. 2. Teres major. 3. Latissimus dorsi. 4. External oblique. 5. Twelfth dorsal vertebra. 6. Trapezius. 7. Vertebral prominence. 8. External occipital protuberence.

FIG. 40.—MUSCLES OF BACK.

1. Levator scapulæ. 2. Trapezius. 3. Latissimus dorsi. 4. External oblique. 5. Rhomboides major. 6. Rhomboides minor. 7. Splenius. 8. Sterno-cleido mastoid.

tion overlapped by the cerebrum (*cerebellum*), and compare its surface with that of the cerebrum; (*c*) the club-shaped mass in front of the cerebellum, and beneath the cerebrum (*medulla oblongata*).

2. Turn back the cerebellum, and tear away the membrane (*pia mater*) which dips down in front of it. Notice (*a*) two round and rather large bodies in front of two small bodies, which make up the *corpora quadrigemina;* (*b*) going from the cerebellum on each side, and disappearing beneath the posterior corpus quadrigeminum of the same side, rounded cords, the *superior peduncles* of the cerebellum; (*c*) a thin layer of nervous substance stretching between the superior peduncles, and covering the front part of the fourth ventricle, which can be exposed by removing this membrane (*valve of Vieussens*). In the interior part of the valve may be seen the roots of the fourth nerve.

3. Examine the under, or ventral, surface of the medulla oblongata. *Do not tear away the pia mater.* (*a*) Examine the two round cords on each side of the middle line (*median*) — the *anterior pyramids.* (*b*) Notice the transverse fibers — the *pons Varolii.* (*c*) Notice two slightly oval elevations, one on each side of the anterior pyramids, the *inferior olivary bodies.* They may be more plainly seen by tearing away the pia mater. (*d*) Observe two broad, rounded bands which appear at the anterior edge of the pons, passing forward, and diverging from one another — the *crura cerebri.* (*e*) Notice two flat bundles of fibers coming obliquely forward over the front part of the crura cerebri, and meeting in the median line to form the *optic chiasma,* the separate parts of which are known as the *optic tract.*

4. Examine carefully the surface. Notice (*a*) the depression (*fissure*) on the upper surface of the cerebrum, running backward,— the *great median fissure,* which separates the cerebrum into two parts (*hemispheres*); (*b*) the groove on the under surface, passing obliquely upward, — the *fissure of Sylvius;* (*c*) the fissure separating the cerebrum from the cerebellum,— the *transverse fissure.*

5. Divide the brain in halves by a longitudinal section through the median fissure. Observe (*a*) the obliquely cut fibers in the decussation of the pyramids; (*b*) the transversely cut fibers of the lower part of the pons; (*c*) the cor-

pora quadrigemina; (*d*) the posterior commissure; (*e*) the *pineal gland;* (*f*) the large *middle commissure,* which occupies a large portion of the third ventricle; (*g*) the *corpus callosum;* (*h*) the *septum lucidum,* deep anteriorly between the corpus callosum and fornix; (*i*) the pia mater entering the transverse fissure, forming at this point the *velum interpositum* situated beneath the fornix and over the *optic thalami;* (*j*) the curious arrangement of the gray matter of the cut portion of the cerebellum, resembling a tree, and known as the *arbor vitæ.*

II. Histology.— Harden a rabbit's or a cat's brain in a two-per-cent solution of ammonium potassium dichromate, putting it into a new solution the following day. The brain should then be cut transversely, put into a fresh solution for a week, and then removed to a fresh solution, in which it can be left two or three weeks. It should then be cut into pieces, care being taken to note what portion the pieces are from, and washed in a dilute solution of alcohol (thirty to fifty per cent) to remove the excess of chromate salt. Stain the pieces by keeping them in strong Frey's carmine for a week or more; wash well in water, soak in gum, cut with a freezing microtome, clear, and mount in Canada balsam.

Try to find the following: —

1. The inner layer of horizontal nerve fibers which form the white substance. Notice how the fibers enter the outer gray substance (*cortex*). The irregular-shaped cells found between the fibers are called *leucocytes.*

2. The layer of small nerve cells at the outside fibrous layer, and forming the fifth layer of the gray substance of the cortex.

3. A layer of small cells of various shapes, with three or more well-marked processes situated beyond the last layer, and forming the fourth layer of the cortex.

4. Following the last layer, one made of pyramidal cells, giving off from their apexes a process which continues upward for some distance. This forms the third layer of the cortex. Note its relative thickness, and the change in the size of the cell.

5. The next layer, of numerous small pyramid cells

with well-marked process pointing outward. This layer forms the second layer of pyramidal cells of the cortex.

6. The outer layer, made up of a fine network of fibrils, in which will be found a few very small cells.

7. See if you can find traces of any blood vessels in the cortex. Where are they most numerous? From what are they derived?

III. Microscopic Structure of the Cerebellum.— Take a portion of the cerebellum, prepared as in the last experiment, making section from the surface of the inner white substance, and at right angles to the direction of the folds. Mount as directed for the cerebral cortex. Notice,—

1. The inner strand of medullated fibers.

2. A layer of cells, formed principally of small cells closely packed together, forming the nuclear layer. The cells have but a small amount of cell substance, so that when deeply stained we only see their nuclei.

3. A single layer of large, somewhat globular cells (*Purkinje's cells*), with large processes which often branch. See if you can trace any of them to the surface of the cortex.

4. The outer layer, consisting of scattered, small, angular cells, with relatively large nuclei, and often giving off one or more branching processes, all intermingled with the fibers from the cells of Purkinje, and imbedded in a close fibrillar network. Notice the numerous capillaries in this layer.

IV. The Cranial Nerves. — 1. Notice the club-shaped bodies extending forward from the fore part of the cerebral hemispheres — the *olfactory lobes*. Trace this and the other pairs as far as you can, to find to what they go, and their functions.

2. Trace the nerves which come from the eyes (the *optic nerves*) to where they join, then cross to pass to their origin in the anterior *corpora quadrigemina*.

3. Back of the optic nerve, near the median line, are two nerves, the third or *motor oculi* nerves, which have their origin in the *crura cerebri*.

4. On each side of the groove between the cerebrum and the cerebellum there will be seen the origin of the fourth pair, or *trochlear nerves*.

5. Just back of the fourth pair notice a pair of nerves which originate by two roots; a large sensory root, connected with a knot, or ganglion (the *Gasserian ganglion*), and a smaller root, which has no ganglion. These are known as the fifth pair, or *trigeminal nerves.* They have their deep origin in the floor of the fourth ventricle.

6. Back and inside of the fifth pair, and arising from the front part of the floor of the fourth ventricle, is the sixth pair, or *abducens nerves.*

7. Emerging from the medulla, between the restiform and olivary bodies, is a pair of large nerves, the seventh, or *facial nerves.* Their deep origin is near that of the sixth, in the fourth ventricle.

8. Back of the seventh pair are the nerves which are distributed to the ear, the eighth pair, or *auditory nerves.* Their deep origin is very complicated, but part of the fibers have their origin in the fourth ventricle.

9. The ninth, tenth, and eleventh pairs arise close together, farther back, and well upon the sides of the medulla. The nucleus of the ninth pair, or *glosso-pharyngeal nerves,* is in the floor of the lower part of the fourth ventricle.

10. Observe the nerves originating by eight or ten filaments from the groove between the restiform and olivary bodies below the glosso-pharyngeal; this pair is the tenth, or *pneumogastric nerves.* They have their deep origin in the lower part of the fourth ventricle, below the area of the ninth. Trace out, and determine its distribution. How does its distribution compare with that of the other cranial nerves?

11. The eleventh pair has two parts, the *spinal accessory* proper, formed by the roots from the cervical spinal cord, and the *bulbular accessory,* whose roots come off just below the pneumogastric. The deep origin of the bulbular accessory is common to it and the vagus.

12. Notice the nucleus near the middle of the floor of the lower part of the twelfth pair, or the *hypo-glossal nerves.*

V. Dissection of the Spinal Cord.— Carefully cut away the bone from the posterior part of the spinal cord by use of the bone forceps, to break away the bone, being careful not to injure the cord.

1. Observe the numerous threads of nerves (*spinal nerves*) given off on each side. Discover if you can how

they get out of the bony canal in which they are placed. Do the fibers which go from the back part (*posterior*) differ from those which go from the front (*anterior*)? The little knots found on the posterior pair are called *ganglia*. Can you suggest a name for them? (If the specimen has been injected, carefully note the relation of the blood vessels.) How many pairs do you find? Does the spinal cord continue the entire length of the bony canal (*spinal canal*) in which it is found? To determine this you will have to cut the covering of the cord from above downward.

2. Note the number and relation of the enlargements of the cord. Can you discover any reason for these enlargements?

3. Can you account for the bunch of fibers at the end of the upper limbs? of the lower limbs? Do they come from the brain or the spinal cord?

Harden a spinal cord in potassium dichromate as directed for the brain. If you cut the spinal cord into transverse pieces, be very careful to mark them so you can tell their relation. Make a transverse section just above the origin of the first nerve of the neck (*cervical nerves*).

Observe,—

1. Covering of the cord.

2. The depression on the anterior side (*anterior fissure*). Examine with two-thirds- or three-fourths-inch objective and *C* eye-pieces.

3. The depression on the posterior side (*posterior fissure*). How do these fissures compare in depth and width?

4. The darker, irregular central mass, the gray matter, and around this the white matter. The projecting portions are called cornua. Notice the portions which project backward (*posterior cornua*), and those which project forward (*anterior cornua*). How do these cornua differ?

5. The hole near the center of the cord (the *central canal*). Is it lined with cells? (Examine with one-sixth-inch objective).

6. Make a careful examination under high power of the gray matter and the white matter.

7. Examine sections from the different regions of the cord, carefully noting the relative proportion of the white and gray matter, and the position and size of the central canal in the different regions.

8. Make longitudinal and transverse sections of the posterior ganglion. Make several sections. If the nerve cells of the ganglion are pear-shaped, how can you account for the difference in size of cells in the section you examined?

9. Also make sections of the nerves, and examine them under a lens of high power.

VI. The Sympathetic Chain.— 1. Having traced the pneumogastric to the neck, you will find it bound in the same sheath with the sympathetic nerve. Trace it until you come to the ganglion of the pneumogastric, near which will be found an enlargement of the sympathetic nerve, the *superior cervical ganglion*. Carefully dissect out the rest of the chain. Determine if you can if there is any connection between the spinal nerves and those of the sympathetic. At what points do you find the most nerves given off? See if any of these can be traced to network of nerves and ganglia (*plexuses*). How many pairs of ganglia do you find? How does the sympathetic chain terminate below?

2. Carefully tease out some of the nerve fibers as directed in the experiment given below.

VII. Histology of Nerve Tissue. — 1. *The structure of a nerve.*

a. Remove the skin from the back of the thigh; cut through the tendonous line seen over the femur, and pull the outside mass of muscle outward, which will bring to view a large glistening thread (the *sciatic nerve*).

b. Remove a small portion of the nerve, tease it out very carefully in a one-half-per-cent salt solution, and mount as directed for teased specimens.

Notice,—

(1) The nerve is made up of smaller threads or fibers.

(2) The transparent sheath on its surface appears hyaline, but when seen on edge presents a double outline; this sheath is the medullary sheath. Observe the change in the appearance in the nerve which takes place on standing.

(3) Take a bundle of nerve fibers from the optic nerve, macerate for twenty-four hours in iodized serum, and then prepare by teasing. The gray central line is the axis cylinder.

(4) Harden a nerve in alcohol or dilute chromic acid,

and stain some of the sections in picrocarmine and others in hæmatoxylin. Make transverse sections, and mount in dammar or balsam. Note,— (*a*) the well-defined connective tissue sheath-covering (*neurilemma*), covering the nerve fibers, and varying in size with the fibers which it invests; (*b*) the rings presenting double contour — the medullary sheath.

2. *The Nerve Cells.*—Examine and make drawings of—

(1) Various sections of a posterior ganglion.

(2) Various cells of sympathetic ganglia.

(3) Sections of the spinal cord in the cervical, dorsal, and lumbar regions.

In each case note carefully the shape of the cells, and their relations.

VIII. Nerve Action.— 1. Tickle the inside of the nose with a feather. Account for the action produced.

2. Feign to strike the eye with the finger. Account for the action.

3. Kill a frog with chloroform. Remove the brain, leaving the cord intact.

(1) Pinch the toe, and note action produced.

(2) Dip small bits of sponge in a dilute acid (strong vinegar will do), place them on different parts of the body, and notice the difference in action produced. After each application, thoroughly wash the parts with water.

(3) Put a drop of acid on the flank of the frog. Note the action. Hold the foot on the side to which you added the acid. Explain the action.

(4) Expose the sciatic nerve near its origin. Pinch the terminal parts, and notice results.

THE NERVOUS SYSTEM — TEXT.

Need.— Motion is essential to our existence and best development. Not only must the organs act, but they must act in harmony, both as to degree and kind of motion. These movements must not be made in reference to the body alone, but also to the environment of the body, to which it must adapt itself. But this power of motion,— sense of relationship,— not only of its own parts, but of the environment controlling and directing, cannot originate within the bones and muscles. It must come from without these organs. The system of organs by which this is accomplished is

called the *nervous system.* The more highly developed this system, the higher and richer the physical and intellectual life of the organism. Hence man stands pre-eminent among created forms, the masterpiece of the Architect of the universe. Should we not prize our high estate? The impressions (*sensations*) from without are signs of the change of our environment; the impulses to the organs causing them to act so as to bring our body in harmony with our environment are called *stimuli.* The condition of the parts of the body, and the harmonious action to adapt these parts to secure the best development, is brought about in the same way — by sensations and stimuli.

Divisions. —The nervous system, for convenience of study, may be grouped into two divisions, the Central Nervous, or *Cerebrospinal System,* and the Sympathetic, or *Ganglionic System.* We have learned from our dissections that the central nervous system is found in the neural cavity, and that it sends off branches (*nerves*) to various parts of the body. It consists of the brain, spinal cord, and cranial and spinal nerves. The sympathetic is located in the ventral cavity, and consists of a double chain of nerve masses (*ganglia*), numerous scattered ganglia, plexuses, and sympathetic nerves.

The last is not a distinct system, as was once thought, but only an outlaying part of the same system, and in close connection (Fig. 57) with it, most of its fibers being derived from the central nervous system.

As we have seen, nerves go to nearly every organ and tissue of the body. That these various parts may work in harmony, it is essential that the entire system be under the control of a central guiding force. This we find in the *brain.*

While the brain is the central and controlling organ, on account of its simple structure, it is better to consider first the spinal cord.

THE SPINAL CORD.

General View of the Cord. — The cylindrical mass of nervous matter contained in the spinal canal is called the

spinal cord. It extends from the margin of the *foramen magnum* of the occipital bone to the first lumbar vertebra, where it ends in a slender thread, the *filum terminale,* which lies among a mass of nerve roots called the *cauda equina* (Fig. 54). It is from seventeen to eighteen inches long and three fourths of an inch in diameter in a person of average height.

The spinal cord gives off thirty-one pairs of nerves, which leave the spinal canal by openings called the *intervertebral foramen.*

The spinal cord is not of uniform size, but presents two enlargements: (1) the lumbar swelling, beginning at the first lumbar and extending to the eighth dorsal, and being widest near the third lumbar. From the lumbar swelling, the cord retains very nearly the same diameter until it reaches the level of the seventh cervical, when it has a (2) fusiform enlargement, which extends to the bulb, being broadest at the level of the fifth or sixth cervical nerve. The sectional area of the cord increases from below upward,

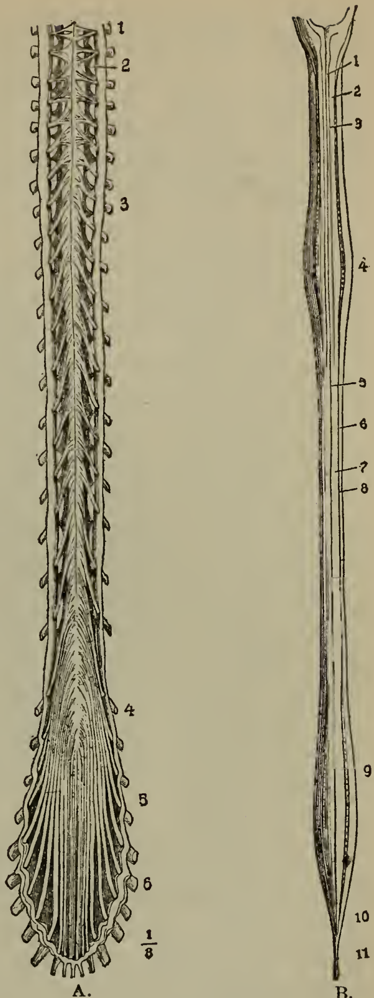


Fig. 54. A.—With Coverings Partly Removed.

1. Second cervical nerve. 2. Ligamentum dentata. 3. First dorsal nerve. 4. First lumbar. 5. Cauda equina. 6. First sacral.

Fig. 54. B.—General View of the Spinal Cord Without Coverings.

1. Funiculus gracilis. 2. Funiculus cuneatus. 3. Posterior intermediate fissure. 4. Cervical enlargement. 5. Posterior median fissure. 6. Posterior lateral fissure. 7. Posterior column. 8. Lateral column. 9. Lumbar enlargement. 10. Terminal cone. 11. Beginning of filum terminale.

but not regularly, the irregularity being due to the lumbar swelling (Fig. 54). The spinal cord does not completely fill the spinal canal. It is invested by three membranes, with a space between the outer and middle ones, and another space between the middle and inner ones.

Membrane of the Cord.—The outer membrane is the *dura mater*, and is continuous with that of the brain, but differing from that of the brain, in that it is not connected to the bony walls, but separated from them by areolar tissue and a plexus of veins. It sends off tubular sheaths along the spinal nerves for a short distance, and becomes lost with their investing membranes as they leave the intervertebral foramen.

Beneath the dura mater is found a thin, delicate membrane, the *arachnoid membrane*. It is also continuous with the cerebral arachnoid above. It also passes as a sheath for the nerves, and is separated from the dura mater by a narrow space termed the subdural space.

Beneath the arachnoid is a vascular membrane (*pia mater*) closely attached to the surface of the cord, dipping down into its fissures, and sending investments along the nerves. The pia mater is loosely connected with the arachnoid by strands of connective tissue, forming a spongy network, but there is a considerable space between the two, which is called the subarachnoid space. This space contains a fluid called the *cerebrospinal fluid*. This may be considered as a serous, or lymphatic, space, and is in communication with the perivascular lymphatics of the small arteries that pass into the nervous tissue of the brain, and spinal cord from the pia mater, as well as with lymph spaces in the nervous matter itself. It is also in communication with the central canal of the cord and the ventricles of the brain, by a small opening through the pia mater in the roof of the fourth ventricle. This opening is called the *foramen of Magendie* (Fig. 64).

This fluid differs from ordinary lymph, (1) in its small per cent of proteids; (2) in the absence of cells; (3) in the absence of a fibrin ferment. It finds its way back into

the circulation by escaping into the lymphatics of the nerves in the subarachnoid space around their roots, and from them into the general lymphatics of the body.

The pia mater is attached along its whole length on each side, between the anterior and posterior roots of the spinal nerves, to a narrow fibrous band of connective tissue, which is joined at intervals by tooth-like projections to the dura mater. The band is called the *ligamentum denticulatum.*

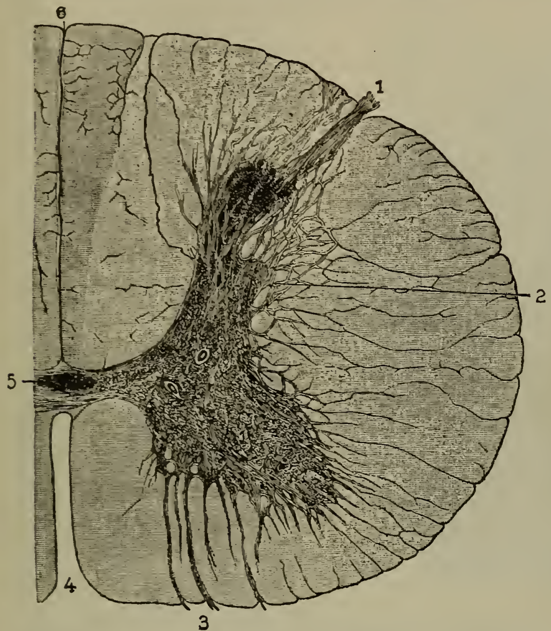


FIG. 55. A.—TRANSVERSE SECTION OF SPINAL CORD IN CERVICAL REGION.

1. Posterior root. 2. Reticular formation. 3. Anterior root. 4. Anterior fissure. 5. Central canal. 6. Posterior fissure.

We can best get a view of the general structure of the cord by an examination of transverse sections of various parts. While these differ somewhat, they have many features in common. Fig. 55 illustrates the general structure. There are two fissures running along the length of the cord, which divide it into a right and a left half. This fissure, called the median fissure (Fig. 55), is divided into two parts; one in front, the anterior median fissure (Fig. 55), which is the wider but shallower of the two, and is closely invested by the pia mater, and one in the rear, the posterior median fissure (Fig. 55). The posterior fissure is not a true fissure, but more of a septum of

connective tissue and blood vessels passing nearly to the center of the cord. There are also fissures or furrows on the side of the cord, known as *lateral fissures.* The one at the line of attachment of the posterior roots of the spinal nerves is called the *posterior lateral groove* (Fig. 54); the one at the attachment of the anterior roots, though not marked by any furrow, and spread over some space, may be regarded as indicating another division of the cord. In the upper part of the cord there is a slight longitudinal furrow (Fig. 54), the *posterior lateral furrow.* It is not far from the posterior median fissure. Each half of the cord is thus divided into four columns: the portion between the anterior median fissure and the anterior roots, the *anterior column;* between the line of origin of the anterior roots and posterior roots, the *lateral column;* between the line of origin of the posterior roots and the posterior lateral furrow, the *posterior median column;* between the posterior lateral and posterior median fissure, the *posterior column.*

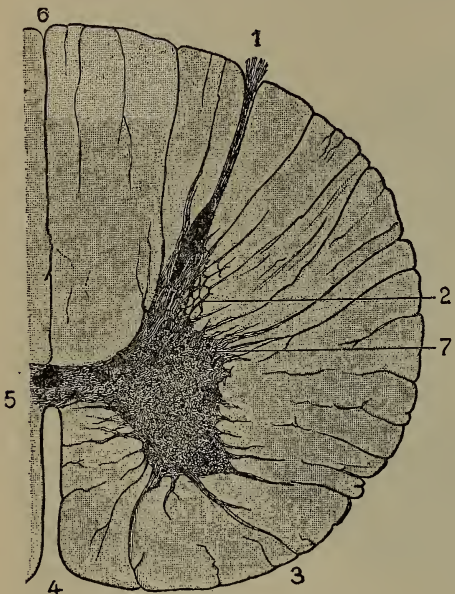


FIG. 55. B.—TRANSVERSE SECTION OF SPINAL CORD IN DORSAL REGION.

1. Posterior root. 2. Reticular formation. 3. Anterior root. 4. Anterior fissure. 5. Central canal. 6. Posterior fissure.

The transverse sections also show us that the cord consists of gray and white matter: the white matter is on the outside, and gives to the cord its white opaque appearance; the gray matter is on the interior, and is arranged in the

form of a crescent or comma-shaped mass in each half, being joined in the middle by a mass of gray matter, the gray *commissure*. In the center of the gray commissure is the central canal, the cord, which is lined in early life by ciliated columnar epithelium. At the bottom of the anterior fissure is a transverse connecting portion of white substance, the anterior, or *white commissure*. At the outer side of each crescent the gray matter forms a kind of network (*processus reticularis*). The horns of the crescent are named from their position, the anterior and posterior. As we have seen, the amount and form of the gray matter varies in different parts of the cord.

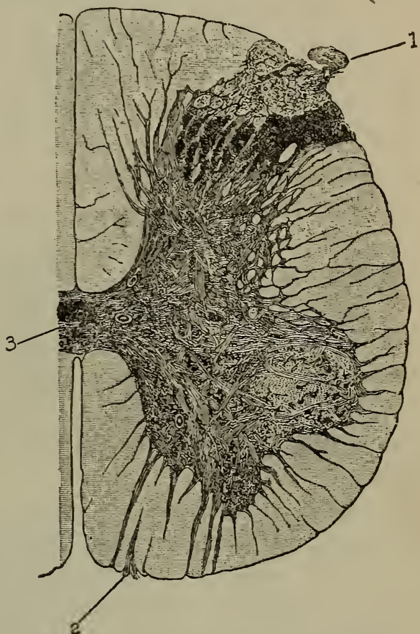


FIG. 55. C.—TRANSVERSE SECTION OF SPINAL CORD IN LUMBAR REGION.
1. Posterior root. 2. Anterior root. 3. Central canal.

In the cervical region (Fig. 55) the anterior cornu is large and broad and the posterior cornu narrow; in the dorsal (Fig. 55) and thoracic regions both anterior and posterior cornu are narrow; in the lumbar region (Fig. 55) the anterior and posterior cornu are broad. The relative proportion of white and gray matter varies in the different regions of the cord (Fig. 55), being least in the thoracic and dorsal regions and greatest in the lumbar region. The sections of white matter increase in absolute size, in a steady manner, on the whole, from below upward. The gray matter varies greatly in absolute area. At the level of the third lumbar region the gray matter is much reduced. At the level of the

sixth cervical region it again increases to a considerable amount.

Microscopic Structure of the Cord.— The white matter of the cord is composed of medullated nerve fibers, but these do not have the sheath of Schwann, which runs for the most part in a longitudinal direction, so that they appear in cross section as minute circles. Their size varies in different parts of the cord, those near the surface being larger than those near the gray matter. The supporting tissue of the fibers is a peculiar fibro-cellular structure, the *neuroglia,* and in part connective tissue. The neuroglia is abundant at the surface of the cord, and extends into the gray matter forming the gelatinous substance (*substantia gelatinosa*) upon which rests the epithelium of the central canal; it also tips the posterior cornu.

The gray matter is made up of nerve cells with branching processes, fine medullated fibers and neuroglia, and non-medullated fibers. The nervous filaments run in various directions, and while they do not form a plexus proper, by anastomosing they make an interlacement of extreme complexity.

The cells of the gray matter are more or less regularly arranged in areas or columns. The cells of the anterior cornu are called the *vesicular column* of cells (Fig. 55). They are large multipolar cells, each of which has an axis-cylinder process, continuous with a fiber of the anterior root of a spinal nerve, the other process breaking up into a fine meshwork of fibrils. These cells are most numerous in the cervical and lumbar enlargements. The cells of the posterior horn are much smaller, and any axis-cylinder they may possess does not seem to be connected with posterior fibers, but pass to the anterior horn. A group or tract of medium-size cells, situated at the inner angle of the base of the posterior horn, is called *Clarke's column* (Fig. 56). There is also another group in the lateral cornu of gray matter.

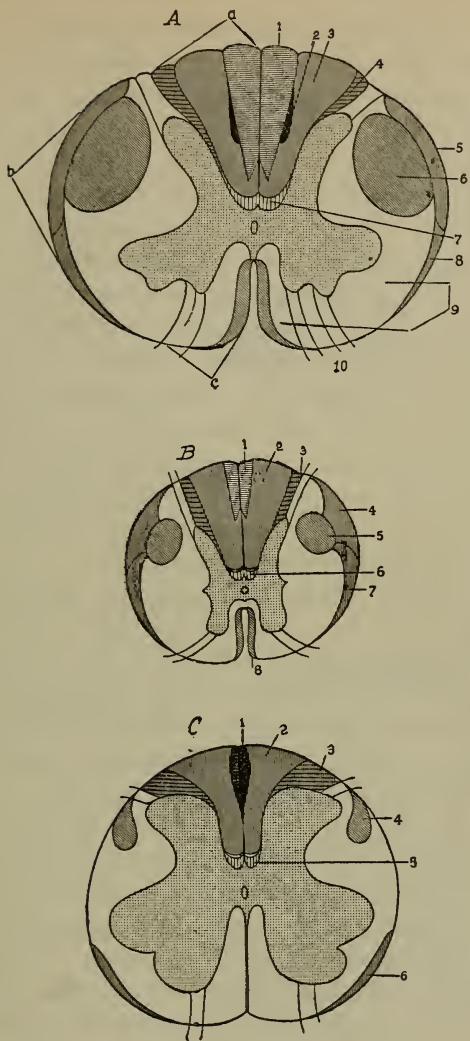


FIG. 56.—MOTOR AND SENSORY TRACTS OF THE SPINAL CORD.

A. Section of cervical region. *a.* Posterior column. 1. Column of Goll. 2. Comma tract (Schultz's comma). 3. Column of Burdach. *b.* Lateral column. 5. Direct cerebellar tract. 6. Crossed pyramidal tract. 8. Antero-lateral ascending tract (tract of Gowers). *c.* Anterior column. 10. Direct pyramidal tract.

B. Section in dorsal region. Parts numbered as in A.

C. Section in lumbar region. Parts numbered as in A.

COLUMNS OF WHITE MATTER.

We have seen that by the superficial fissure the white matter of the cord is divided into columns; these, on closer examination, are found to be made up of other tracts.

The principal means by which we determine this are: (1) By cutting the fibers loose from the nerve cell (the *Wallerian method*). If the fiber is separated from its cell, it wastes or degenerates. The degenerated fibers can be distinguished by their appearance under the microscope, especially if treated with special straining reagents. (2) By noticing the growth of the nerve fibers in the embryo (the *embryological method*). (3) By the different parts of nervous impulses by electrical charges. The tracts may thus be grouped into two classes: those which degenerate below the cut or injury (lesion) in the cord, known as *descending degeneration,* and those which degenerate above the lesion, known as *ascending degeneration.*

The principal tracts or columns of descending degeneration are, —

1. **The Crossed Pyramidal Tract.**— This is found in the lateral column at the outer part of the posterior horn of gray matter throughout the length of the cord. This tract consists of rather large fibers mingled with smaller ones. It descends from the opposite side of the cortex of the brain, the fibers crossing at the pyramids of the medulla (Fig. 56).

2. **The Direct Pyramidal Tract.**— It is situated in the anterior column (Fig. 56), by the side of the anterior median fissure. Its fibers are of large size. It gradually diminishes in size on passing downward, ending near the middle of the dorsal region. It may belong to a portion of the crossed pyramidal tract, the fibers not crossing (*decussating*) in the medulla, but passing probably to the opposite side in the cord itself, through the anterior white commissure.

3. **The Antero-lateral Descending Tract.**— This tract is situated in the antero-lateral column. Its fibers are connected with cells in the brain cortex on the same side as that of the column.

4. The Comma Descending Tract.— This is a small tract in the upper part of the cord, in the middle of the postero-lateral column. It is uncertain whether its fibers originate from cells higher up in the cord or from the descending fibers of the posterior root.

The principal tracts of ascending degeneration are:

1. The Antero-lateral of Gowers.— This is situated at the outer part of the cord (Fig. 56), and mingles with the corresponding descending tract. Its fibers can be traced upward to the cerebellum. They probably have their origin in cells in the posterior cornu of the cord.

2. The Direct Ascending Cerebellum Tract.— This tract is situated at the outer part of the cord, external to the crossed pyramidal tract in the dorsal and cervical regions. Its fibers probably arise from the axis-cylinder processes of the cells of Clarke's column.

3. The Postero-lateral Ascending Tract, or Column of Burdach.— This is situated between the superficial postero-lateral tract and the comma tract (Fig. 56). It is chiefly composed of large fibers that are continuous with the fibers of the entering posterior roots, and after passing for some distance in the cord, numerous filaments pass off into the gray matter.

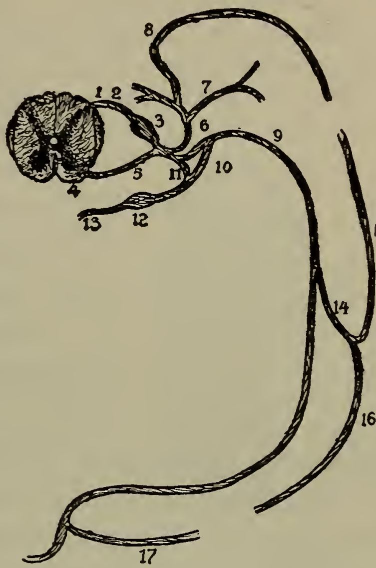


FIG. 57.—DISTRIBUTION OF SPINAL NERVES.

1. Posterior horn (cornu) of gray matter of spinal cord. 2. Posterior root of spinal nerve. 3. Posterior ganglion. 4. Anterior horn of gray matter. 5. Anterior root of spinal nerve. 6. Posterior division. 7. External branch. 8. Posterior cutaneous branch. 9. Anterior division of intercostal nerve. 10. Recurrent nerve. 11. Ramus communicans. 12. Sympathetic ganglion. 13. Ramus efferens. 14. Lateral cutaneous branch. 15. Posterior branch. 16. Anterior branch. 17. Anterior cutaneous nerve. (Modified from Henle.)

L. of C.

4. The Posterio-mesial Tract, or Column of Goll.— This is situated in the area (Fig. 56) between the posterior median fissure and the column of Burdach. The fine fibers of which it is composed are derived from the posterior root fibers, and pass up this column into the medulla, where they end among cells of the nucleus gracilis.

5. The Tract of Lissauer.— This is a small tract, close to the posterior root, from which its fine fibers are derived.

The Spinal Nerves.— In our dissection of the spinal cord we found thread-like bodies (*nerves*) attached to the spinal cord. These are the spinal nerves. They are arranged in pairs. They originate by two roots, one from the posterior part of the cord, the *posterior root;* the other from the anterior part of the cord, the *anterior root.* The two roots pass through separate openings in the dura mater, but unite before passing through the vertebral foramen to form a mixed nerve, from which branches are given off to the dorsal and ventral parts of the body, as well as a visceral branch (*ramus communicans*) to the sympathetic system (Fig. 57).

Before the roots unite, a ganglion is found on the posterior root, where the roots lie in the intervertebral foramen. By experimental excitation of the fibers of the posterior root it is shown that it contains nerves which go to the spinal cord (*afferent*), while similarly the anterior root is shown to contain nerves which come from the cord (*efferent*). The anterior also contains a few afferent fibers, but the posterior is entirely afferent or sensory.

The anterior roots arise, by several converging bundles of fibers, from the anterior column of white matter; and on tracing the fibers into the gray matter of the cord many of them are found to be continuous with the axis-cylinder processes of the large cells in the anterior horn. These fibers go from the cord to the skeletal muscles, and are called motor fibers, as they carry stimulus for muscular contraction. Some of the fibers pass by these cells, and do not appear to be connected with them. The exact origin of these fibers has not been clearly determined, but some pass to the

white commissure, and probably have their origin in the cells of the anterior horn of the other side. Some of these pass to the posterior horn. The anterior root contains, besides the motor fibers to the skeletal muscles, vasomotor and secretory fibers. The posterior fibers enter the cord in a more compact mass than the anterior fibers, and after their entrance into the cord, separate into two sets. The first consists of somewhat large fibers, and passes into the postero-lateral white column, proceeding for the most part upward, and entering either the posterior median tract or the adjacent gray matter, and some continue on through the gray matter to the anterior horn.

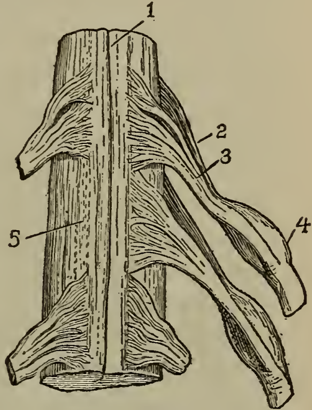


FIG. 58.—ORIGIN OF SPINAL NERVES.

1. Anterior median fissure. 2. Posterior root. 3. Anterior root. 4. Spinal ganglion (posterior). 5. Antero-lateral fissure.

The second or small fibers enter at the tip of the posterior horn, and join the ascending fibers in the tract of Lissauer. As the fibers of the posterior root enter the cord, they divide into two principal branches, running upward and downward in this posterior white column, or the adjacent posterior horn, and give off collateral branches, which run inward toward the gray matter, and end in a network of fibrils around the nerve cells. The fibers of the posterior root originate in the cells of the posterior root ganglion. A longitudinal section of this ganglion shows it to consist of a number of cells with nerve fibers passing through them. Most of these cells are pear-shaped and unipolar, and the cell process joins the traversing nerve fiber by a T-shaped union, though it is possible that some fibers may pass through without any connection with a cell.

Section of the root between the ganglion and the cord leads to the degeneration of the central part, or the part in connection with the cord; while the peripheral part, or the

part in connection with the ganglion, remains unaffected. Section below the ganglion leads to waste in the peripheral part, but not in the central part. Section of the anterior root leads to degeneration in the peripheral part, but not in the central part. From this we learn that the center of nutrition (*trophic center*) for the sensory or posterior fibers, is the posterior ganglion; that for the motor anterior fibers, the cells of the gray matter of the cord. There are few fibers, however, which remain unaffected in the peripheral end of a cut anterior root, the end containing a few degenerate fibers among the mass of unaffected ones. These are known as the *recurrent sensory fibers*. If the anterior root of a spinal nerve be divided, and the peripheral end stimulated, there is not only movement of the muscles supplied by the nerve, but in some cases there are evidences of pain. This is called *recurrent sensibility*. This is caused by a few sensory fibers which leave the cord by the posterior roots, but turn back into the anterior root. By dividing the posterior root, recurrent sensibility disappears.

There are thirty-one pairs of spinal nerves. The spinal cord is regarded as a series of segments, each segment corresponding to a pair of nerves. Each segment of this groundwork consists of a central mass of gray matter connected on each side with an anterior and a posterior root, thus forming a segmental nervous mechanism. By some, the spinal segment has been compared to ganglion. A ganglion and the gray matter of a spinal segment both contain nerve cells, but with few exceptions they have little or no resemblance. Their structure compared is as follows: —

1. In a ganglion the constituent nerve cell is a development of the axis-cylinder of a fiber into a nucleated cell body, which lies on the course of a fiber, or where the fiber divides into two or more; and we have evidence that the nucleus, with its cell substance, exercises an important influence on the nutrition of the nerve fiber and its functional activity. But we have no satisfactory evidence that the cell can automatically originate nervous impulses, or exercise any marked

transforming power over the impulses passing along the fiber. The gray matter of the spinal segment is especially possessed of the reflex and automatic, as well as other powers.

2. In a ganglion the nerve fibers may divide, and in small peripheral ganglia the divisions may give rise to very delicate fibrils; but the fibers or fibrils resulting from the division leave the ganglion to follow their appropriate courses. In the spinal cord, both efferent and afferent fibers divide in such a way that their divisions are lost to view in the gray matter. All the processes, except the axis-cylinder process, divide into branches, and seem to end in nervous fibrils, lost to view in the gray matter. While our knowledge of the junction of the posterior root is imperfect, what we know leads us to believe that the fibers of the posterior root, either by the means of cells or by direct division of the axis-cylinder, break up into fibers which are lost in the gray matter. We have evidence that the anterior and posterior roots are continuous, not by a gross continuation of the axis-cylinder, but in a peculiar way through the divisions of branches of nerve cells or axis-cylinders, forming a nervous network: while the *fibers are not continuous histologically, they are so functionally.*

Functions of the Spinal Cord. — The spinal cord is both a conductor of nerve impulses and a center of reflex and automatic action. By means of its fibers it has connection with the body, and by means of its relation to the brain acts as the great conductor of afferent impulses to the brain, where they may be perceived, and the impulses sent back by the cord to the afferent fibers. We should bear in mind that there is no continuous nerve fiber running from the end organ to the cells of the brain by means of the spinal cord, and an efferent fiber returning from the cells of the brain by means of the cord to the muscle or gland to be stimulated (as some of us have been taught), for this is not true. There is a line of communication, the plan of which we shall soon learn.

It serves also as a trophic center for the efferent nerves, and as a center of automatic and reflex action.

By experiment and observation the paths of the sensory and motor impulses have been made out; while not perfectly determined, yet they have been sufficiently so to aid us very much in learning the paths which the afferent and efferent impulses take.

1. Paths of Sensory Impulses of the Cord.— Afferent impulses find their way to the cord by the posterior root, and pass up some or all of the ascending tracts, i. e., of ascending degeneration to the brain. But the tract taken by the different impulses has not been definitely determined. Recent experiments have, however, definitely proved that all sensory impulses do not decussate or cross over in the cord, as was formerly supposed, but that they pass up the same side for the most part, and cross chiefly in the medulla to reach the opposite side of the brain. Mott thinks that impulses of touch, pressure, and the muscular sense pass up the same side, but that sensations of pain pass up both sides.

2. Paths of Motor Impulses in the Cord.— Efferent impulses pass from the brain along the two pyramidal tracts, for the greater part in the crossed pyramidal, these tracts being undoubtedly the channels of voluntary impulses. For the most part they originate in the cortex of the cerebrum at one side, in the pyramidal decussation in the medulla. A few fibers do not cross in the medulla, but pass down in the direct pyramidal tract to decussate in the cord by the anterior white commissure. The vasomotor impulses to the limbs travel along the lateral columns of the cord on the same side.[1]

[1] By section (cutting the cord entirely across) and hemisection (cutting the cord half across), we learn that,—

1. Complete transverse section of the spinal cord leads to,—

(a) Loss of motion of the parts supplied by the nerves, below the section, on both sides of the body.

(b) Loss of sensation in the same regions.

(c) Degeneration, ascending and descending on both sides of the cord.

2. Hemisection leads to,—

(a) Loss of motion of the parts supplied by the nerves below the section on the same side of the body as the injury.

(b) Loss of sensation in the same region. The loss of sensation is not a very prominent symptom, and is limited to the sense of localization and to the muscular sense. The animal can still feel sensation of pain, and of heat and cold.

(c) Degeneration, ascending and descending nearly entirely confined to the same side of the cord as the injury.

Reflex and Automatic Action of the Spinal Cord.— In vertebrate animals, and especially in man, the central nervous system (cerebrospinal) contains, in addition to nerve fibers, a number of nerve centers, localized in certain parts, yet having the power of influencing each other. They do not have direct connection by means of nerve fibers, as was once thought, but rather their cells, by means of their branches, and also by reason of the molecular groundwork of the cord, are so related that the excitation of one may affect the other, as we shall learn later on. These centers of the brain and spinal cord may be regarded as forming connected groups of cells endowed with the power of regulating some function of the body. Thus we have a respiratory center, a vasomotor center, a control center, tonic centers, and a perspiratory center.[1]

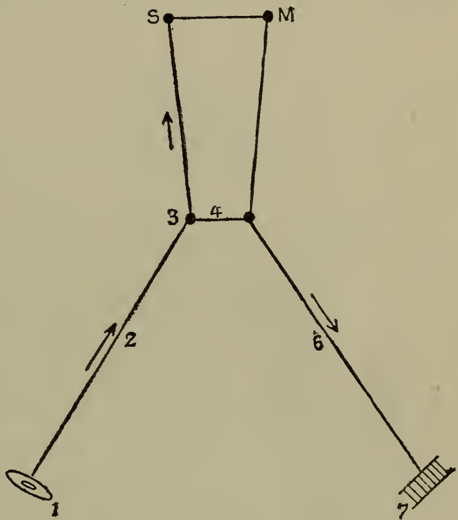


FIG. 59.—OLD IDEA OF REFLEX ACTION.
1. Sense organ. 2. Sensory nerve. 3. Posterior horn of gray matter. 4. Connection with anterior horn. 5. Anterior horn. 6. Efferent, or motor, fibers. 7. Muscle. (Notice in this case there is a direct connection between parts.)

Physiologically speaking, the whole process of the nervous system may be spoken of as automatic, reflex, or psychic.

In reflex action we have the immediate efferent response independent of the will; i. e., these centers have the power to respond to afferent impulses. The spinal cord may be considered as made up of a number of these centers. It should be remembered that any part of the brain may act as a reflex center. Especially is this true of the medulla or bulb.

[1] It is proper to say that this explanation of the facts is not accepted by all physiologists. See J. Loeb's "Physiology of the Brain" for other views.

The mechanism of reflex action may consist of the following parts: (1) A sentient surface or peripheral sense organ; (2) from these an afferent tract to the reflex center; (3) connection of the reflex center with efferent tracts; (4) a muscle, gland, secreting cell to receive the efferent impulse. These form what is called a reflex arc (Fig. 60).

The old idea as to the manner in which it takes place is as follows: (1) A sensory nerve fiber is stimulated (Fig. 59); (2) the impulse is carried by an afferent fiber to a sensory nerve cell; (3) then transmitted to a motor nerve cell by branching processes connecting the two (Fig. 60); (4) and these are then reflected down the motor nerve fibers (efferent) to the muscle or gland which it excites.

In order to understand the present notion it will be necessary for us to consider the present idea of the structure of the nervous system. The study of the nervous system by the method introduced by Golgi has led to some new conceptions as to its structure (see Appendix). "The whole nervous system consists of nerve cells and their branches, supported by neuroglia in the central nervous system, and by connective tissue in the nerves. Some of the branches of a nerve cell break up almost immediately into smaller branches, ending in an arborescence, or fine twigs; these branches are called *dendrons,* and the fine twigs *dendrites;* one branch becomes the long axis-cylinder of a nerve fiber. This large branch is called the *axis-cylinder,* or *neuraxon.* By most writers the term neuron is applied to the complete nerve-unit (Fig. 84), which consists of the body of the cell and all its branches. It has been supposed by some observers that the axis-cylinder process is the only one that conducts nerve impulses, the dendrons being rootlets to imbibe nutriment for the nerve cell. This conclusion has not, however, been generally accepted. The dendrons may be nutritive, but it is believed that they also, like the rest of the nerve units, are concerned in the conduction of nerve impulses. A strong piece of evidence in this direction is the fact that the fibrils of the axis-cylinder may be traced through the body of the cell into the dendrons.

It is essential that we keep in mind the fact that each nerve unit (*neuron*) is anatomically independent of every other nerve unit. There is no anastomosis of the branches of one nerve cell with those of another; the branches interlace and intermingle, and nerve impulses are transmitted from one nerve unit to another, but not by continuous structure. The structures are contiguous, but not continuous.

According to this view, reflex action takes place as follows: (1) Excitation occurs at the sensory nerve fibers; (2) the impulse is transmitted by the sensory nerve fiber to the nerve center, where it ends, not in the nerve cell, but by arborizing around a nerve cell and its dendrons. The only nerve cell in actual continuity with the sensory nerve fiber is the one in the spinal ganglion from which it grew. (3) While the terminal arborization of the sensory nerve fiber interlaces with the motor nerve cell, yet by this contiguity, or touching, the motor nerve cell sends an impulse by its axis-cylinder process to the muscle.

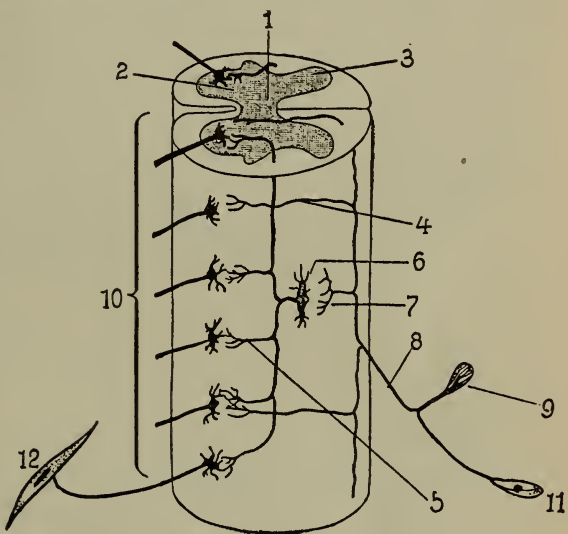


FIG. 60.—MECHANISM OF REFLEX ACTION.

1. Gray matter of spinal cord. 2. Anterior horn. 3. Posterior horn. 4. Sensory collateral joining the motor cells directly. 5. Motor collaterals joined to a cell. 6. Cell joining with collateral (4). 7. Sensory collateral fibers. 8. Sensory, or afferent, nerves. 9. Posterior ganglion. 10. Motor, or afferent, nerve (and cells). 11. Sense organ. 12. Muscle. When the course is from 11, 8 to 4 and across to 10 and 12, it is called direct reflex; when through 11, 8, 7, 6, and 5 across to 10 and 21, indirect reflex. (Modified from Henle.)

In such animals as the frog, the cord alone can carry out

numerous reflex acts, some of which may be very complex. After the brain has been removed from a frog, it recovers from the shock in about an hour; and if protected from any stimulating influence, remains still until it dies. But if a stimulus be applied to the skin of one foot, that foot will draw up. This is an example of a single reflex action, and illustrates what is often called *the law of unilateral reflection.* Generally a slight excitation of a sensitive region causes a reflex movement in the neighboring muscles. A stronger stimulus not only leads to a movement of the same side, but to a less degree in the opposite side also. If the stimulus be very strong, or if the cord be in a very excitable condition, the sensory impulse may be reflected along most of the motor nerves, producing what is called a reflex spasm. This spreading has been called the *law of radiation or diffusion.* Some drugs, as strychnine, so affect the gray matter of the spinal cord, that the slightest touch on the skin puts all the muscles into a state of spasmodic contraction. When one of the toes of a brainless frog is dipped into diluted sulphuric acid, the leg is not drawn up for some time.

From this we may learn that a weak impulse may not itself be capable of producing a reflex act, but that a succession of such impulses sent to the cord may combine their influence until a movement is caused. This is known as a *summation of stimuli.*

The stimulation of the flank of a frog with acid causes the leg of the same side to be swept over the spot; and if this leg be held, the other leg tries to remove the irritation. So well directed are these movements, that at first sight they seem to be acts of intelligence, but a more careful view shows that they are mechanical, as is shown by the fact that a decapitated snake will coil around a red-hot iron as readily as around a stick in contact with its body. These actions call for complicated movements involving groups of muscles requiring complex co-ordination. The movements seem to be protective or purposive in character.

From these and similar experiments we learn that excita-

PLATE IV.

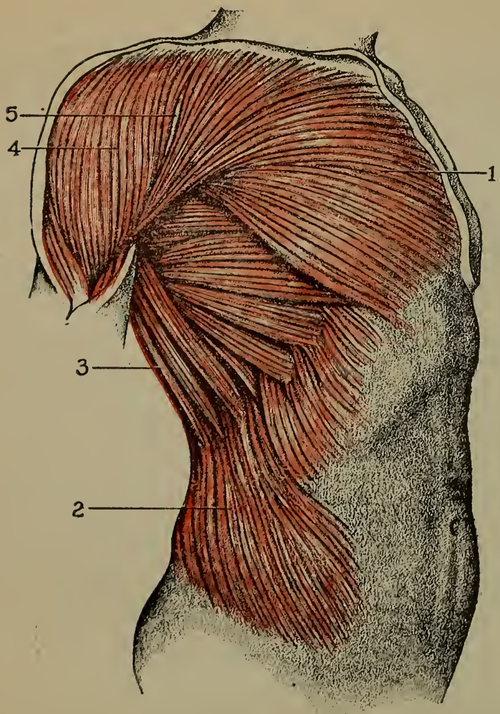


Fig. 41.—Muscles of Trunk.

1. Pectoralis major. 2. External oblique. 3. Serratus major. 4. Deltoid. 5. Cephalic vein.

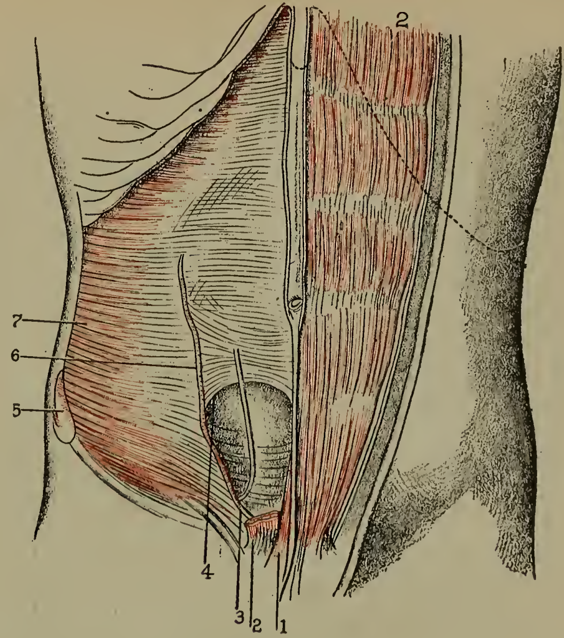


Fig. 42.—Abdominal Muscles.

1. Pyramidales abdominis. 2. Rectus abdominis. 3. Superficial epigastric artery. 4. Linea semilunaris. 5. Cut portion of external oblique muscle. 6. Cut portion of internal oblique. 7. Transversalis abdominis.

tion of the cord in many parts thus tends to spread in various directions, but with a preference for certain paths marked out by the structure and habits of the cord. Reflex action occurs more readily in a brainless frog than in one whose brain has not been removed. The reason for this seems to be that the brain exercises an inhibitory power over the cord, thus restricting its activity. This inhibitory power is nicely illustrated by the great ease with which reflex action occurs, and by the absence for a time of any sense of pain to a soldier wounded in battle, when his mental energies are all centered on the fight. If the knee be half bent, and tapped sharply on the patella tendon, the rectus muscle of the thigh contracts, and raises the leg. This action is called tendon reflex.

This "knee jerk," as it is called, is present in health, but absent or exaggerated in some diseases, as those of the cord; it is therefore of great importance in aiding the physician in determining certain diseases. There is doubt as to this being a true reflex action, as the time between the blow and the contraction is not as short as in muscular contraction. The cutting of the nerve, coming to this muscle from the cord, destroys the action.

The time required for any reflex act varies much with the strength of the stimulus, being less for strong stimuli. The velocity varies also with the condition of the cord, being much slower when the cord is exhausted, and in case of disease. The time for reflex action has been estimated at from .01 to .06 of a second.

Automatic Action of the Spinal Cord.—Foster defines automatic action as an action which appears to be not immediately due to any change in the circumstances in which the organ or body is placed, but to be the result of changes arising in the organ or body itself, and determined by causes other than the influence of the circumstances of the moment.

Some automatic actions are of a continued character; others repeated in regular rhythm, as the beating of the heart; others still very irregular and variable, as those automatic actions we attribute to the will.

We have an illustration of this automatic action in the rhythmic beat of the heart and the rhythmic discharge of the respiratory impulse. While these are not due to the changes taking place in the cord, they serve well to illustrate the nature of automatic action. In automatic power the brain surpasses the cord.

One of the most marked cases of the automatic action of the cord is the maintaining of the muscular tone of the skeletal muscles. While this automatic action is not caused directly by afferent impulses, it is greatly influenced by them, in that they bring about a greater intrinsic change in the centers which are the causes of the automatic action. We can thus account for the greater automatic action of the brain. The cause of this automatic action is due to the metabolism of the nerve tissue, anabolism, or building up of the explosive, being followed by katabolism, or its discharge.

THE BRAIN.

That part of the cerebrospinal system contained in the cranial cavity is called the brain, or *encephalon.*

Weight of the Brain.—The brain of the average adult human female weighs 44.5 ounces, and that of the male, 49.75 ounces. Cases are recorded in which the brain attained a weight of 74.8 ounces, one such case being that of an idiot boy. In the European, the average maximum weight is reached between the thirtieth and fortieth years. The minimum weight in the European is 34.39 ounces in the female, and 39.96 ounces in males.

The weight of the brain of a gorilla was found by Professor Owen to be fifteen ounces. In the healthy body the relation of the weight of the human brain to that of the body is as one to forty-one.

Parts of the Brain. — Its principal parts are: (1) The large mass above and in front, the *cerebrum;* (2) the smaller mass to the rear and beneath the cerebrum, the *cerebellum;* (3) the club-shaped body just in front of the cerebellum, and which seems to be the continuation of the spinal cord,

the *medulla oblongata,* or bulb, and overlying as seen from the ventral surface, the cerebellum; (4) the quadrate mass just above the medulla, showing transverse fibers connecting it externally with the two sides of the cerebrum, the *pons Varolii.* Internally, it is found to be continuous with the medulla.

The striated bundles of nervous matter emerging from

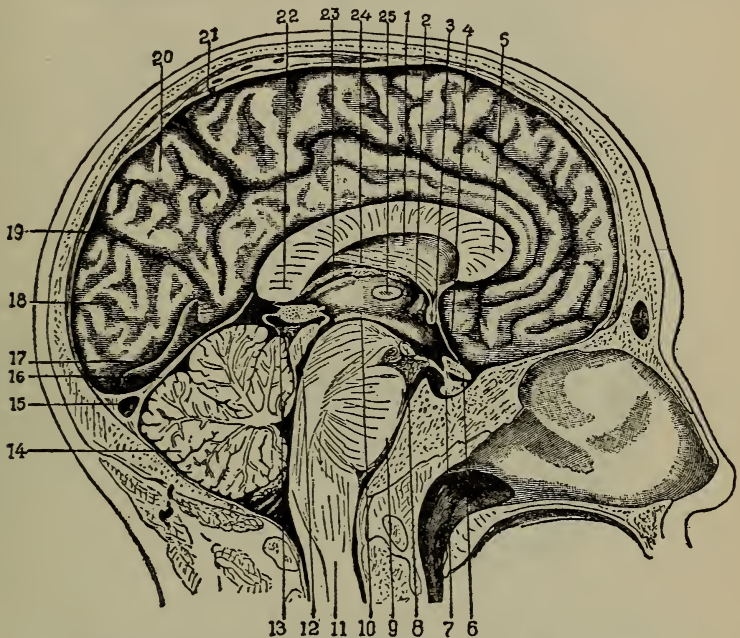


FIG. 61.—SECTION OF CRANIUM AND BRAIN ON MEDIAN LINE.

1. Septum lucidum. 2. Foramen of Monro. 3. Anterior commissure. 4. Lamina terminalis. 5. Corpus callosum. 6. Chiasma. 7. Pituitary body. 8. Corpora mammillaria. 9. Pons. 10. Sulsus hypothalam. 11. Medulla. 12. Lamina quadrigemina. 13. Pineal gland. 14. Cerebellum. 15. Transverse sinus. 16. Tentorium. 17. Calcarine fissure. 18. Cuneus. 19. Parieto-occipital fissure. 20. Precuneus (quadrate lobe). 21. Sup. sagittal sinus. 22. Corpus callosum (posterior). 23. Choroid plexus. 24. Fornix. 25. Middle commissure.

the pons and entering the under part of each cerebral hemisphere as they diverge, are the *crura cerebri.*

The small triangular plate of brain tissue traversed by many arteries, and lying between the diverging peduncles of the crura, is called the posterior perforated space. The two small white bodies near by, the function of which is unknown, are the *corpora albicantia.*

The *tuber cinereum* is a small eminence of gray matter situated in front of the corpora albicantia, attached to the junction of the optic nerves, which is called the *optic commissure.* The hollow conical process passing from the tuber

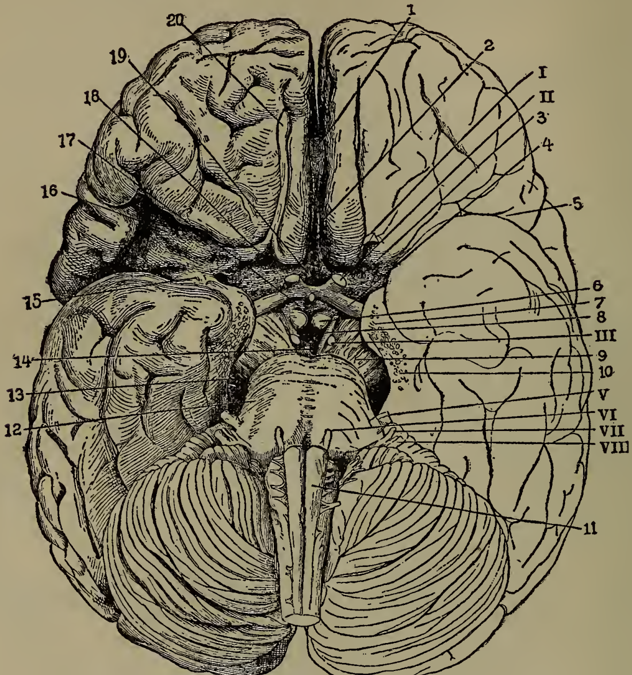


FIG. 62.—INFERIOR SURFACE OF BRAIN.

1. Corpus callosum (genu). 2. Gyrus subcallosus. 3. Anterior perforated space. 4. Optic tract. 5. Fissure of Sylvius. 6. Corpora mammillaria. 7. Gyrus hippocampus. 8. Tegmentum. 9. Crus cerebri. 10. Substantia alba. 11. Medulla oblongata. 12. Pons. 13. Thalamus. 14. Posterior perforated space. 15. Limen insulae. 16. Island of Reil. 17. Tuber cinereum. 18. Origin of olfactory lobe. 19. Lamin. termin. 20. Olfactory bulb.

Roman numbers refer to the pairs of cranial nerves. I. Olfactory. II. Optic, etc. See page 127.

cinereum to the small, reddish body is the *infundibulum.* The small, red body is called the *pituitary body,* and is of unknown function. Unless the dissection has been carefully made, the pituitary body will be removed with the dura mater, as it is inclosed in this membrane.

The club-shaped masses of gray matter lying in the grooves on the under surface of the frontal lobes of the

cerebrum and on each side of the fissure (median or longitudinal fissure), are the *olfactory* tracts and bulbs.

To learn of the internal structure, we make section of the brain in various directions. Fig. 61 represents a section made on the median line from above downward. By a careful study of Figs. 61, 63, 64, 65, and 66, and a comparison with the dissections that have been made, a good idea of the general structure of the brain may be had.

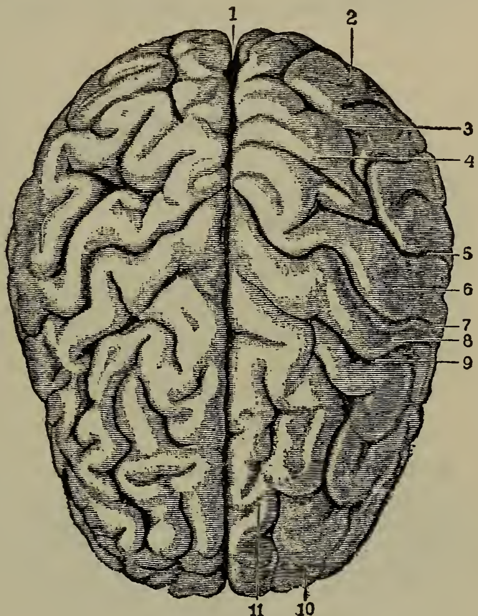


Fig. 63.—Superior Surface of Brain.
1. Longitudinal fissure. 2. Occipital convolution. 3. Interparietal fissure. 4. Superior parietal lobe. 5. Posterior central fissure. 6. Posterior central convolution. 7. Central fissure. 8. Anterior central convolution. 9. Anterior central fissure. 10. Median frontal convolution. 11. Superior frontal convolution.

As we have seen, the spinal cord is continuous with the medulla, becoming the medulla at the large opening (*foramen magnum*) in the base of the skull. The central canal, which we found traversed the entire length of the spinal cord, widens on entering the medulla, into a lozenge-shaped cavity called the *fourth ventricle*.

The cerebellum overhangs the fourth ventricle. The peculiar tree-like appearance of the cerebellum on section, due to the arrangement of the white matter, is called the arbor vitæ. The fibers of the medulla pass upward, and cross into the pons Varolii, beyond which will be seen the crura cerebri.

The four hemispherical masses situated in the upper and back part of the crura cerebri, from which they are separated

by a small channel passing from the fourth ventricle, are the *corpora quadrigemina,* two of which may be seen in Fig. 66.

Just above these is a small cone-shaped body, the *pineal gland.* It may be of interest for us to know that by some scientists this is thought to be the remnant of a third eye, and also that some psychologists have considered it as the seat of consciousness. Of its true function, however, nothing is known. The small channel which leads from the fourth to the third ventricle is the *aquæductus Sylvii.* The third ventricle is a narrow median cavity, bounded on each side by the internal surface of an oval mass of matter that projects internally, known as the *optic thalamus* (Fig. 66). The third ventricle thus lies between the optic thalami, and the gray matter of the thalami being connected across the narrow cavity by the soft commissure. In the roof of the third ventricle is the *fornix,* which is covered by a double fold of the *pia mater,* called the *velum interpositum.* The fornix is a longitudinal arch of white fibrous matter united to the *corpus callosum* behind and in front to a thin partition, the *septum lucidum* (Fig. 65). The space between the two layers is called the *fifth ventricle.* The fifth ventricle has no connection with the other ventricles, and is not regarded as a true ventricle. All the other ventricles are in communication, and contain a

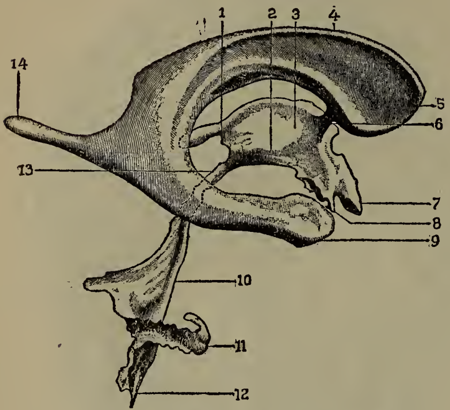


FIG. 64.—CAST OF THE VENTRICLES OF THE BRAIN.

1. Recess of the pineal gland. 2. Fissure of hypothal Monroi. 3. Third ventricle. 4. Lateral ventricle. 5. Anterior horn of lateral ventricle. 6. Foramen of Monro. 7. Optic recess. 8. Recess of infundibulum. 9. Inferior horn of lateral ventricle. 10. Fourth ventricle. 11. Lateral recess of rhomboid fossa. 12. Foramen of Magendie. 13. Aqueduct of Sylvius. 14. Posterior horn of lateral ventricle.

small quantity of fluid (*the cerebrospinal*). The fornix (Fig. 65) descends to the base of the brain. On each side from the front part of the third ventricle an aperture (*the foramen of Monro*) (Fig. 64) leads by a G-shaped connection to the lateral ventricle in each cerebral hemisphere. These may be brought to view by slicing a brain horizontally down to the corpus callosum (Fig. 65), and removing it sufficiently.

FIG. 65.—TRANSVERSE VERTICAL SECTION OF THE BRAIN.

1. Median longitudinal stria. 2. Corpus callosum. 3. Caudate nucleus. 4. Internal capsule. 5 and 6. Lenticular nucleus. 7. External capsule. 8. Temporal lobe. 9. Optic chiasma. 10. Optic recess. 11. Pia mater. 12. Anterior perforated space. 13. Anterior commissure. 14. Claustrum. 15. Pillar of fornix. 16. Septum lucidum (pellucidum).

Each lateral ventricle is an irregularly curved cavity, extending in the substance of the corresponding cerebral hemisphere for about two thirds of its length. It is lined, as are all the true brain ventricles, by ciliated epithelium. Each of the lateral ventricles consists of a central cavity, or body, and three small cavities, or cornua; the body of each lateral ventricle is separated in front from its fellow by the septum lucidum. The roof of each of these ventricles is formed mainly by the under surface of the corpus callosum. The rounded mass of nervous matter in the front part of the floor of each of these ventricles is called the *caudate nucleus* of the corpus striatum. The deeper part of the corpus striatum, the lenticular nucleus, is imbedded in the mass of each cerebral hemisphere. There is also found in the lateral ventricles a part of the upper surface of the optic thalamus, the inner sides forming the lateral boundaries of the third ventricle. Each thalamus rests upon and is connected with

one of the crura cerebri, and has on its outer and hindermost part two small elevations, called the *corpora geniculata.* A tract of white fibers (*the internal capsule*) continuous with the lower or anterior portion of the crus, and lying between the lenticular nucleus on the outer side and the optic thalamus and caudate nucleus on the inner side, passes upward to the outer layer (*cortex*) of the cerebrum, some of its fibers diverging on the way, forming a fan-shaped mass of white, the *corona radiata.*

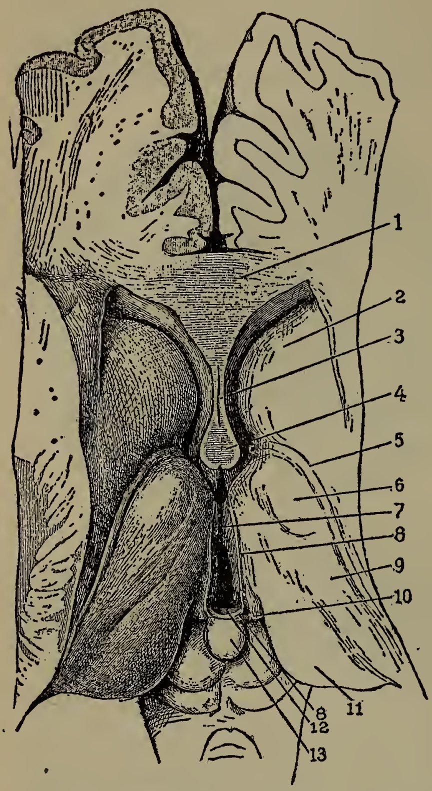


FIG. 66.—1. Corpus callosum. 2. Caudate nucleus. 3. Septum lucidum. 4. Pillar of fornix. 5. Stria termin. 6. Tubercle of superior thalamus. 7. Median commissure. 8. Peduncle of Pineal gland. 9. Optic thalamus. 10. Triangle of the peduncle of the pineal gland. 11. Pulvinar. 12. Posterior commissure. 13. Pineal gland.

The cerebral hemisphere, two ovoid masses separated by the median fissure, and connected by the corpus callosum, makes up about seven eighths of the mass of the brain. The surface of the cerebrum is molded into eminences, which form convolutions, or *gyri*, separated from each other by small fissures, or *sulci.* The depressions on the surface mark off each hemisphere into five lobes: *frontal, parietal, occipital, temporo-sphenoidal,* and *central,* or *island of Reil.* For the names of the fissures and the relation of these lobes, see Fig. 76.

Like the other portions of the nervous system, the brain consists of gray and white matter, all of its parts being more or less connected by numerous fibers.

The gray matter is similar in structure to that of the spinal cord, consisting of nerve cells, neuroglia, and minute blood vessels. It is found principally (1) on the surface (*cortex*) of the brain, (2) in special areas throughout the substance of the brain, (3) lining the ventricles, and (4) in the ganglia and bodies; as, the *olfactory lobes, corpora striata, optic thalami, corpora quadrigemina* at the base of the brain. The white matter consists of fibers of various sizes medullated, but without the primitive sheath, and arranged in bundles separated by neuroglia. These fibers may be arranged into three systems by the direction they take: (1) Diverging or *peduncular fibers* (*projection fibers*), which connect the hemispheres with the lower portions of the brain and the cord, and which are in a great measure direct prolongations of the axis cylinders of the nerve cells of the cortex; (2) transverse, or *commissure fibers* (including the fibers of the corpus callosum, and the *anterior* and *posterior commissures*), which connect the two hemispheres; (3) associated fibers, which connect different structures of the same hemispheres. (See Fig. 73.)

The Covering of the Brain.— The brain, like the spinal cord, is invested by three membranes (Fig. 67) or *meninges*: the dura mater, the pia mater, and the arachnoid membrane.

The *dura mater*, the external one, is a dense, fibrous membrane closely attached to the inner surface of the skull, forming the periosteum for the inner surface of the bones of the cranium. It is continuous with the dura mater, that forms the outer coat of the cord, and it becomes intimately attached to the bony cavity of the skull before passing through the foramen magnum. On reaching the skull, it divides into two layers, and at various places the two layers separate to form channels, or *sinuses*, for venous blood. This membrane also sends off three processes, or membranous partitions: (1) The *falx cerebri*, which lies vertically between the two hemi-

spheres in the median fissure; (2) the *tentorium cerebelli* (Fig. 67), forming a sloping vaulted partition at the back between the cerebrum and the cerebellum; (3) the small *falx cerebelli* between the hemispheres of the cerebellum.

The *pia mater* is the membrane which directly invests the brain, dipping down into its fissures and sulci. It is fibrous, delicate, and vascular. From its surface numerous small blood vessels pass into the brain substance. At the

FIG. 67. A.—COVERING OF THE BRAIN.

Section through portion of cranial bone and upper surface of brain. 1. Cranial bone. 2. Cerebrum. 3. Dura mater. 4. Subdural space. 5. Arachnoid membrane. 6. Subarachnoid space. 7. Pia mater. 8. Vein from diploe. 9. Subdural process. 10. Sagittal sinus. 11. Lateral sinus.

transverse fissure it is prolonged into the lateral ventricles, and over the third ventricle forming the triangular fold of the pia mater lying just beneath the fornix (Fig. 67), where it can be seen when the fornix is cut through and raised, and also the choroid plexuses. The fourth ventricle also receives a prolongation over its posterior roof.

Lying just outside of the pia mater is the *arachnoid,* the most delicate of the coverings of the brain. It does not so closely invest the brain as does the pia mater, as it passes over the fissures and sulci without dipping down into them. There is a space between the dura mater and the arachnoid, known as the *subarachnoid space.* It is not uniform in size, its course being at the base of the brain much widened. As in the spinal cord, thin bands of connective tissue connect the pia mater and arachnoid, and in the meshes of the subarachnoid space thus formed is the cerebrospinal fluid. The

subarachnoid space communicates with the ventricles of the brain and the central canal by a small hole in the pia mater of the roof of the fourth ventricle, called the *foramen of Magendie*.

The Medulla Oblongata, or Bulb.— This is the bond between the spinal còrd and the brain proper. It is by means of the bulb that the shifting of the white fibers of the cord takes place, many of the fibers crossing (*decussating*) over to the opposite side. As we have seen, the narrow central canal of the cord widens out into the wide fourth ventricle (Fig. 64) on the posterior surface. The gray matter of the cord becomes separated into four masses on each side by the passage of fibers across the anterior and posterior horns. There is also additional gray matter superadded. There are two tracts of fibers which can be clearly traced through the bulb to higher parts; the *pyramidal tracts* to the cerebrum, and the *cerebellar tract* to the cerebellum. There are other tracts, which appear to terminate in groups of cells that act as relays between the fibers of the cord and the white matter of the brain.

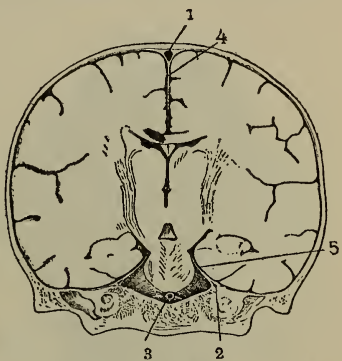


FIG. 67. B.—COVERING OF THE BRAIN.

Vertical section through cranial cavity and brain. 1. Superior sagittal sinus. 2. Petrosal sinus. 3. Basilary artery. 4. Falx cerebri. 5. Tentorium.

The bulb is pyramidal in shape, with the base above. It is related to the cord below and to the pons above. It is about one inch long, nearly one inch wide, and three fourths of an inch thick. Its surface shows fissures and columns; each half consists of an anterior pyramidal body, olivary, restiform body, and posterior pyramid (Fig. 68). The bulb has on its ventral surface the anterior median fissure continuous with that of the cord. The two bundles of white matter on each side of the anterior fissure are the anterior pyramids, and are separated from a round elevation, known as the oli-

vary body (Fig. 68). These pyramids are formed of fibers from the cord, some of the fibers being continuous below with those of the cord which form the direct pyramidal tract, but most being derived from the lateral column of the cord of the opposite side, known as the crossed pyramidal tract. The crossing of the lateral pyramidal fibers seen in the interior fissure is spoken of as the *decussation of the pyramids.*

The two strands of fibers which make up the anterior pyramids degenerate downward when lesions or injuries of the cortex occur in the region known as the motor area. From this we know these fibers are efferent, or motor. In their course they are continuous through the *crusta,* or inferior part of the crura, with fibers in the internal capsule that pass to the region of the cerebrum, called the motor area (Fig. 78).

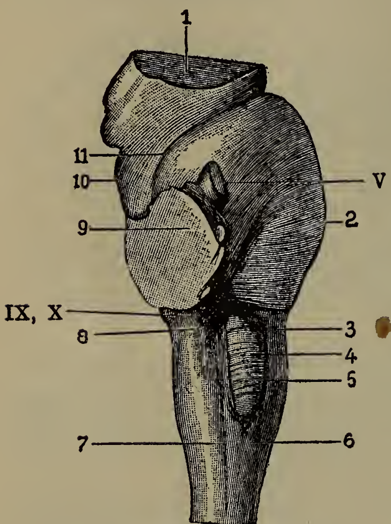


FIG. 68.—SIDE VIEW OF MEDULLA.
1. Crus cerebri. 2. Pons. 3. Pyramids. 4. Olivary body. 6. Lateral fissure. 7. Posterior lateral fissure. 8. Restiform body. 9. Arm of Pons. 10. Connecting arm. 11. The fillet. Roman numerals refer to the respective pair of cranial nerves as numbered.

Lying between the olivary body and the posterior fissure of the bulb is a band of fibers consisting of afferent, or sensory, fibers from the posterior columns of the cord, and some of which, those forming the direct cerebral, enter the inferior peduncles of the cerebrum, and are known as the *restiform body.*

The strand of fibers which come up from the posterior median column of the cord, appearing below the restiform body, are called the posterior pyramid of the *funiculus gracilis.* The strand near by from the posterior external column forms the *funiculus cuneatus.* Both of these strands terminate within the medulla, in the masses of gray matter,

called the *nucleus gracilis* and the *nucleus cuneatus,* respectively. From these nuclei, fibers pass across the central gray matter to parts of the brain above, their crossing being known as the upper, or *sensory decussation.*

As we have stated, the cavity within the bulb is the fourth ventricle, and is formed by the widening of the central canal into the space formed by the divergence of the posterior pyramids, or funicule, which forms its lateral boundaries in its lower half. The superior peduncles of the cerebrum, which pass downward and outward, form the lateral boundaries of its upper half. The pointed lower portion of the lozenge-shaped cavity thus formed is called, from its resemblance to a writing pen, the *calamus scriptorius* (Fig. 69).

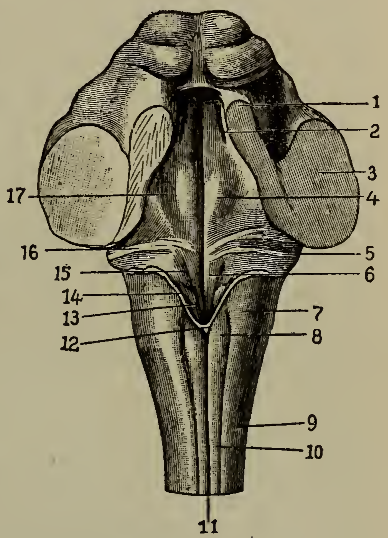


Fig. 69. — Posterior View of Medulla. 1. Connecting arm of Pons. 2. Locus cœruleus. 3. Arm of Pons. 4. Funiculus teres. 5. Striæ acusticæ. 6. Trigorium hypoglos. 7. Tubercule cuneatus. 8. Clava. 9. Funiculus cuneatus. 10. Funiculus gracilis. 11. Posterior fissure. 12. Apex. 13. Calamus scriptorius. 14. Fourth ventricle (band of). 15. Ala cinerea. 16. Area acusticæ. 17. Fovea superior.

The upper angle of the ventricle reaches up to the level of the pons, and communicates by the aqueduct of Sylvius with the third ventricle (Fig. 64). Its roof is formed in the upper part by a thin layer of white matter streaked with gray, called the valve of Vieussens, in the lower half by the reflection of the pia mater from the cerebrum. The posterior surface of the bulb and pons form the floor of the fourth ventricle. The white fibers, which emerge from the slight fissure in the floor, are known as the auditory striæ, but we are in doubt as to how far they are connected with the auditory nerve. A number of small elevations on the floor correspond to the

nuclei of gray matter, from which arise several cranial nerves. The olivary bodies and the two small detached masses, called the *accessory olivary nuclei,* furnish additional gray matter to the bulb. Gray matter traversed by longitudinal and transverse fibers forms the greater part of the central and lateral parts of the bulb, and on account of this structure this portion is called the *reticular formation.*

Functions of the Bulb.— From what has been said, we may now appreciate the importance of the bulb. We might judge from its complex structure that it has a varied function, which is true. It acts (1) as a conductor from the cord to the brain; (2) as a collection of nerve centers, both automatic and reflex; (3) as means for the decussation of the fibers and the transition of the gray matter from the interior of the cord to the exterior of the brain (cortex); (4) as a source of most of the cranial nerves, being placed as it is, so that all the impulses passing between the spinal cord and the brain must pass through the bulb. For the greater part, the afferent impulses pass along the anterior pyramids where the decussation (*anterior pyramidal decussation*) occurs of those fibers from the cord that have not already crossed in the cord; i. e., of the crossed pyramidal tract. The fibers of the pyramidal tract are believed to decussate at various levels in the cord by the anterior commissure. The path of the sensory, or efferent, impulses is not completely made out, but it is probably, for the most part, along the posterior pyramids by way of the fibers which terminate in the nucleus gracilis and nucleus cuneatus of the bulb. From these nuclei, fibers pass around the front of the bulb to the opposite side in the strand, called the *superior pyramidal decussation* (*sensory decussation*). Some of the fibers are thought to decussate in the pons, and it is well established that the decussation of the fibers connecting the spinal cord and the brain is complete in the crura cerebri, so that all impressions to and from the hemispheres of the brain pass across the middle lines; injury to either hemisphere affects the sensation and motion of the opposite side of the body.

The importance of the bulb as a nerve center is shown

by the fatal results when it is injured or seriously diseased. Hanging is effective as a mode of putting criminals to death because the sudden displacement of the upper cervical vertebræ by the sudden drop of the body, when the trap is sprung, so injures the cord and its connection as to produce instant death. The piercing of a needle point in the center of the bulb produces instant death; and, on account of its control over the vital organs, the bulb is called the vital knot. It has been shown by experiment on the lower animals that the whole brain, with the exception of the bulb, may be gradually removed and the animal still live for some time; and it has been shown that the spinal cord may be removed up to the origin of the phrenic, a nerve arising from the third and fourth cervical nerve and sending fibers to the diaphragm, without producing death for some time.

NERVE CENTERS.

Nerve centers, as to their action, may be grouped into the following classes: (1) automatic centers, (2) reflex centers, (3) control centers, (4) tonic centers, and (5) psychic centers.

Automatic centers are those which do not depend upon sensory impulses for the discharge of their motor impulses, as the rhythmic action of the heart and the respiration; while they do not depend upon sensory impulses, the most active automatic centers are those which have close connection with sensory fibers. The most active automatic nerve centers are in the brain. They also exist, as we have already seen, in the cord.

Reflex Centers, are those in which a sensory impulse is essential to the discharge of nervous impulse of motion (afferent impulses).

Control Centers, are those whose influence may be directed to controlling the action of subsidiary centers. The more important are the respiratory, vasomotor, and sweat centers.

Psychic centers are those in which consciousness and the will have control over the afferent impulses. The more important centers of the bulb are: —

1. *The Respiratory Center.*—This is bilateral, and is situated behind the origin of the vagus nerve on each side of the posterior part of the calamus scriptorius. The branches of the vagus distributed to the lungs are efferent nerves, and they appear to be stimulated according to the condition of the blood as regards the proportions of the oxygen and the carbon dioxide. The impulse reaching the bulbular center is reflected along the efferent, or motor, fibers of the phrenic, intercostal, and other nerves associated with the respiratory movements. This center is also automatic in its action, and the venous blood circulating in the bulbular center itself may excite it and lead to its automatic action.

2. *Cardiac Center.*— This is also located in the bulb, one part of which gives origin to fibers whose stimulation accelerates the action of the heart through the sympathetic; another part of which gives origin to fibers whose stimulation inhibits the action of the heart through the vagus.

3. *The Vasomotor (Vasoconstrictor) Center.* — This is situated in the floor of the bulb a little above the calamus scriptorius. The center is bilateral, and controls the nerve supply to the unstriped muscles of the arteries, intestines, etc. Under ordinary conditions it keeps the arteries in a state of tonic contraction. Stimulation of the center leads to contraction of the walls of the arteries and a general rise of blood pressure; inhibition of the center leads to dilation of the arteries and a fall of the blood pressure. This center controls subordinate centers in the cord.

4. *Center of Mastication.*— This is believed to be situated in the bulb, the afferent fibers being the sensory branches of the fifth and the tenth pairs of cranial nerves, and the efferent, the motor branches of fifth and twelfth cranial nerves.

5. *Center for Salivary Secretion.*— This is also located in the bulb.

6. *Other Centers.* — In the medulla there are also centers for deglutition, vomiting, and coughing.

Reflex Centers of the Cord.— The chief reflex centers of the cord are: —

1. *Muscular Tonic Center.*— By means of this the spinal cord has an influence over the muscular system which keeps the muscles of the body in a continual state of slight con-

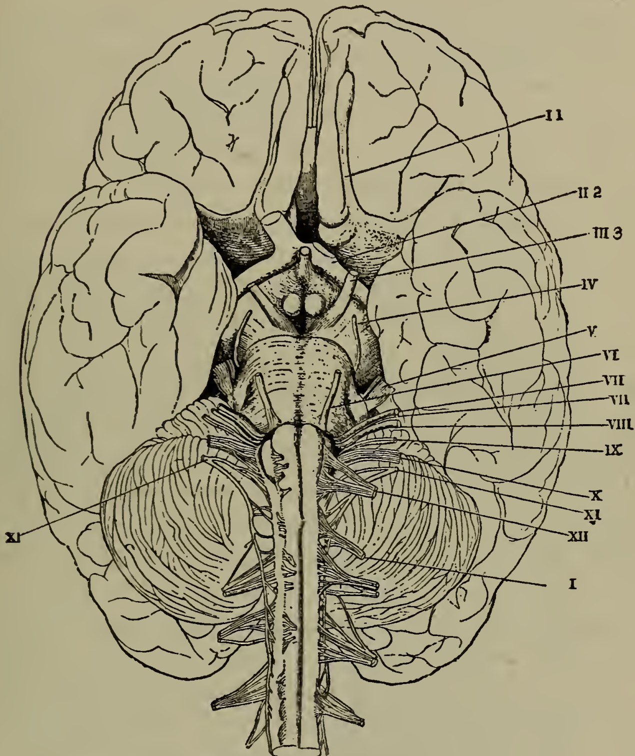


FIG. 74.—SUPERFICIAL ORIGIN OF CRANIAL NERVES.
The Roman numerals refer to the respective pairs of nerves.

traction, which is called muscular tone. If the brain be injured or removed, the muscles still retain their tone; but if the cord be injured or diseased, the muscles lose their tone, and become flabby and loose. If the sciatic nerve of one leg of a frog be sectioned, the muscles of that limb become relaxed.

2. *Defecation Center.*— This center is located in the

lumbar region of the cord. It sends impulses which control the regular and tonic contraction of the sphincter muscle of the rectum. This center is also under the control of the brain, so that its action may be inhibited or augmented. This gives us the very important principle that constipation may result from nervous affection.

3. *Micturition Center.*— This center is also located in the lumbar region of the cord, and acts in a similar manner to that of defecation. It is stimulated to action by the presence of urine in the bladder or by impulses from the brain, producing the relaxation of the sphincter urethra and the expulsion of its contents.

Other Centers. — There are also fibers which leave the cord by the anterior roots and join the sympathetic that control the secretion of the sweat. There are centers subordinate to those of the bulb which influence vasomotor action and the heart's action.

The Cranial or Cerebral Nerves. — By the cranial nerves is meant those which have their origin either directly or indirectly within the cranium. They consist of twelve pairs. They are mixed in their function, some of special sense, some of general sensation, and others of motion.

Their origin may be spoken of as superficial or deep. Their *superficial origin* extends from the frontal lobe of the cerebrum to the lower end of the bulb (Fig. 74).

We can trace their fibers, however, into the substance of the brain to some special nucleus of gray matter, which is their real or *deep origin* (Fig. 75). With but one exception, that of the olfactory, or first pair, the fibers go from the nuclei of origin and cross within the cranium. They are thus functionally connected with the cerebral cortex of the opposite side. The ultimate distribution of all except the tenth (*pneumogastric*) and eleventh (*spinal accessory*) is to some part of the head.

Their names as to the order in which they pass through the dura mater of the base of the cranuim and their distribution or function are: —

THE CRANIAL NERVES.

PAIR.	ORIGIN.	DISTRIBUTION.	FUNCTION.
1. Olfactory.	Olfactory bulb.	Schneiderian membrane of nose.	Smell.
2. Optic.	Optic thalamus, corpus quadrigeminum, and corpus geniculata, cortex of occipital lobe.	Retina.	Sight.
3. Motor oculi.	Floor of the aqueduct of Sylvius.	All the muscles of the eye, except rectus externus, obliquus superior, and orbicularis palpebrarum.	Motion.
4. Patheticus. (*Trochlearis.*)	Floor of the aqueduct of Sylvius, below the third nerve.	To obliquus superior muscle of eye.	Motion.
5. Trifacial. (*Trigeminus.*)	Floor of the fourth ventricle.	Muscles of mastication, skin, and teeth.	Sensation, motion.
6. Abducens.	Fourth ventricle.	External rectus of eye.	Motion.
7. Facial. (*Portio dura.*)	Fourth ventricle.	Face, ear, palate, tongue, and parotid and submaxillary gland.	Motion, secretion.
8. Auditory. (*Portio mollis.*)	Fourth ventricle, and restiform body.	Vestabular branch to vestibule of internal ear; cochlear branch to cochlea of internal ear.	Hearing.
9. Glosso-pharyngeal.	Fourth ventricle.	Tongue, middle ear, tonsils, pharynx, and coverings of the palate.	Sensation and motion.
10. Pneumogastric. (*Par vagum.*)	Fourth ventricle.	To pharynx, larynx, esophagus, heart, great arteries, lungs, stomach, intestines, liver, and spleen.	Sensation and motion.
11. Spinal accessory.	Fourth ventricle and anterior cornu, as low as fifth and sixth.	Sterno-mastoid and trapezius.	Motion.
12. Hypoglossal.	Fourth ventricle.	Hypoglossus and hyoid muscles.	Motion.

The First, or Olfactory, Nerves. — These arise from a triple root in the under part of the frontal lobe, the olfactory lobes (Fig. 74). They are in reality lobes of the brain. They lie in a furrow on each side of the median fissure of the cerebrum. On reaching the cribriform plate of the ethmoid bone, they expand into bulbs, from the under surface of which ten or twelve fibers pass through the cribriform plate to be distributed to the mucous membrane of the nose, the end organ of smell. As we have noticed, their fibers do not cross, so that sensation received by this nerve does not go to the opposite side of the brain, as it does in the case of the other nerves.

The Second, or Optic, Nerves.— These have their origin in the anterior corpora quadrigemina, the geniculate bodies, and the hinder part of the optic thalami. From this center they pass by what are called the *optic tracts* to form the optic commissure, where there is a partial decussation (Fig. 62) of the fibers; from the commissure they pass to the eyeball, where they expand to form the retina. There are also fibers connecting their nuclei with the visual center of the cortex of the olfactory lobe.

The fibers from the inner or nasal half of each retina decussate and pass backward to the opposite half of the brain, but the fibers from the outer, or temporal, half of the retina do not cross.

The right optic tract, therefore, contains fibers from the outer half of the right retina, and the inner half of the left retina. The visual impression made by light from an object on the left side of the body is transmitted to the right side of the brain. The cutting of one optic nerve produces blindness in the corresponding eye, but a section of one optic tract produces half blindness of each retina (*hemianopia*).

The Third, or Motor Oculi. — This pair arises in three distinct bands of fibers from the gray matter surrounding the aqueduct of Sylvius, near the median line ventral to the canal. The nucleus of origin extends to the back part of the third ventricle as far as the level of the anterior

corpus quadrigeminum. The fibers pass from their origin through the red nucleus to their superficial origin in front of the pons at the median side of each crus. The nerves of the sides decussate. They pass by the two branches to the orbits of the eye, where they are distributed (1) to the lifting muscles (levators) of the eyelids, (2) to the superior rectus, (3) inferior rectus, (4) internal rectus muscles. What movements of the eye are produced by this nerve? There are also fibers which pass to the circular muscles of the iris, and to the ciliary muscle, to regulate the contraction of the pupil and the accommodation of the crystalline lens.

The Fourth, or Trochlearis (Patheticus).— This nerve arises from a nucleus situated below the aqueduct of Sylvius, and extends from the back part of the nucleus of the third nerve to the hind level of the posterior corpus quadrigeminum. The fibers from each side pass round the central gray matter, and, on reaching the valve of Vieussens, they decussate in the median line, and appear at the front of the pons at the lateral edge of the crus. This nerve, like the third, is purely motor in its function, and is distributed to the *superior oblique* muscle of the eye.

The Fifth, or Trigeminus.— In its mode of origin the fifth nerve resembles the spinal nerve in that it has a large sensory root with a ganglion (the *Gasserian ganglion*) and a smaller motor root to join the third branch which comes from it. The nucleus of this nerve is in the floor of the fourth ventricle. The fibers of the sensory root can be traced down the bulb to the upper part of the cord. The nerve appears in its superficial origin at the ventral surface of the pons near its front edge, at some distance from the median line.

In function, the first and second divisions of the nerve which arise entirely from the large root are sensory, being distributed to the face, the teeth, the mucous membrane of the nose and mouth, and to the conjunctiva of the eye. The motor fibers pass to the muscles of mastication, the *tensor tympani,* and *tensor palati.*

The Sixth, or Abducens.— This arises from a compact oval nucleus situated somewhat deeply at the back part of the pons, near the middle of the floor of the fourth ventricle

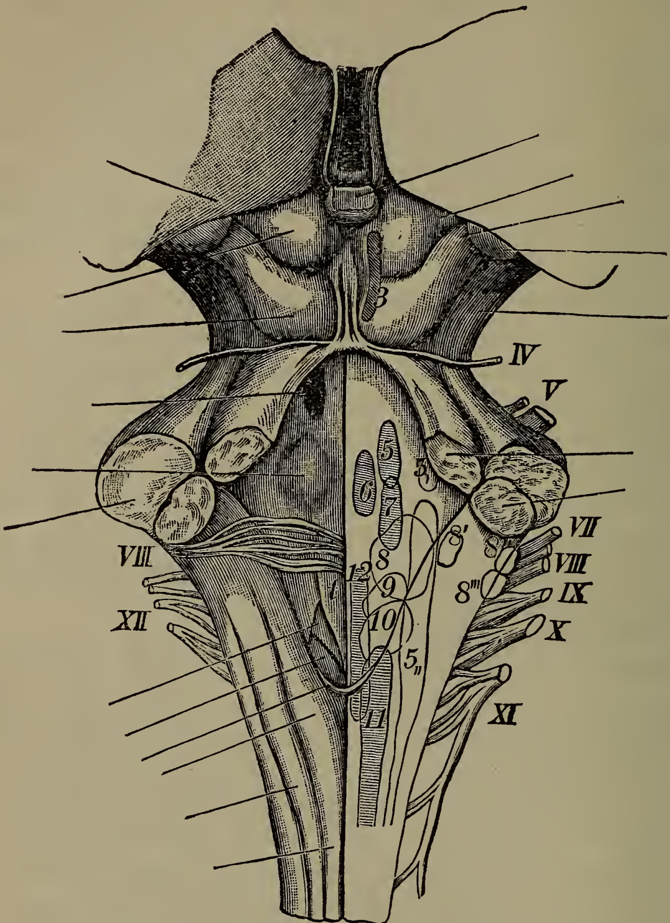


FIG. 75.—DEEP ORIGIN OF CRANIAL NERVES.

Roman numerals refer to the superficial origin of the corresponding pair of nerves; i. e., IV to the fourth pair, and so on; the Arabic numerals to their deep origin, the pair indicated by the number. For the names of the unnumbered parts, see Figs. 61, 62, and 63.

(Fig. 75). It has connection with the nuclei of the third, fourth, and seventh nerves. It is nearer the median line than the nuclei of the fifth and seventh. It reaches the

surface at the posterior portion of the pons opposite the anterior portion of the anterior pyramids. In its function it is entirely motor, and supplies only the *rectus externus.*

The Seventh, or Facial (Portio Dura).—This arises from the floor of the central part of the fourth ventricle behind and in line with the motor nucleus of the fifth to the outside, and deeper down than the nucleus of the sixth. It emerges from the pons lateral to the sixth opposite the front edge of the groove between the olivary and the restiform body. It probably has connection with the hypoglossal nucleus. It is mixed in its function, and supplies (1) the muscles of facial expression; and its paralysis or injury on one side leads to a blank look on that side, with a dropping of the angle of the mouth and a loss of control of the muscle. (2) It sends branches to the submaxillary and parotid glands; it is thus a secretory nerve. (3) Through one of the branches (*chorda tympani*) it has some control over the sense of taste.

The Eighth, or Auditory.— This arises from two nuclei, median and lateral, in the floor of the fourth ventricle, in the anterior part of the bulb in front and to the side of the twelfth nerve. It also has an accessory nucleus situated on the ventral surface of the restiform body. The nerve leaves the surface of the brain from the ventral surface of the fore part of the restiform body at the rear margin of the pons in two roots, the dorsal and the ventral.

Most of the fibers of the dorsal root (*cochlear*) end in the accessory nucleus, but have connection with the median nucleus. Most of the fibers of the ventral root (*vestibular*) end in the lateral nucleus. This is the nerve of hearing. The cochlear branch is the auditory nerve proper, and the vestibular is distributed to the semi-circular canals, utricle and saccule, parts of the internal ear not directly concerned with hearing.

The Ninth, or Glossopharyngeal.— As this nerve is so closely connected with the tenth and eleventh, we shall consider them together. They are considered as divisions of the eighth pair. The nuclei of the ninth and the

eleventh seem to be combined, and appear to consist of two parts, one median, or common, origin, and three lateral origins: (1) the nucleus (*nucleus ambiguus*) which lies on the lateral side of the reticular formation of the origin of the vagus; (2) the one (*fasciculus solitarius*) situated in the bulb, ventral and a little lateral to the combined nucleus, *glossopharyngeal nucleus;* (3) the spinal portion which takes origin from a group of cells in the extreme lateral margin of the anterior cornu, *spinal accessory nucleus.* The combined nucleus reaches from the middle of the floor of the fourth ventricle down to the cord as low as the origin of the sixth or seventh cervical nerves.

Its principal distributions are to the posterior and lateral walls of the upper part of the pharynx, the Eustachian tube, the arches of the palate, the tonsils, and the tongue.

It is mixed in its function. It sends (1) motor fibers to muscles of the palate, pharynx, and tongue, (2) sensory fibers to the parts which it supplies, (3) a nerve of the special sense of taste from its fibers from the fifth.

The Tenth, or Pneumogastric, or Par Vagum. — Its deep origin is as described for the ninth. Its superficial origin is by eight or ten filaments from the groove between the restiform and the olivary body below the glossopharyngeal. It is the most widely distributed of the cranial nerves; the more important points of its distribution are: (1) to a large portion of the mucous membrane of the under surface of the epiglottis, the glottis, and the greater part of the larynx and the cricothyroid muscle; (2) to the mucous membrane and muscle fibers of the trachea, lower part of the pharynx, and to all the muscles of the larynx; (3) to the mucous membrane and muscular coats of the esophagus; (4) to the heart and great arteries; (5) by the pulmonary plexus to the lungs; (6) to the stomach and intestines, and by its terminal branches to the kidneys; (7) and to the liver and spleen.

Throughout its whole course it contains both sensory and motor fibers. We cannot here fully consider the varied function of the pneumogastric nerve, as it can be better learned

when considering the organs to which it is distributed. The more important functions are: (1) motor stimulus to the pharynx, esophagus, stomach, and intestines, to the larynx, trachea, bronchi, and lungs; (2) sensory; and (3) impart vasomotor influence to the same region; (4) inhibitory influence to the heart; and (5) also inhibitory to vasomotor centers; (6) excitosecretory influence to the salivary glands; (7) motor stimulus in coughing, vomiting, etc.

The Eleventh, or Spinal Accessory. — This arises by two distinct organs, one from a center of the floor of the fourth ventricle in connection with the common nucleus mentioned above, the other from the side of the anterior cornu of the spinal cord as low down as the fifth or sixth cervical nerve. The fibers from the two origins come together at the jugular foramen, but separate into two branches, the inner of which arising from the medulla, joins the vagus (pneumogastric), to which it gives motor fibers, while the outer gives fibers to the trapezius and sternomastoid muscle.

The Twelfth, or Hypoglossal.—This arises from a very long nucleus in the bulb near the middle of the floor of the fourth ventricle, and extends back to the level of the olivary bodies. Its superficial origin is from a groove between the anterior pyramid and olivary body. Its fibers are distributed to the muscles of the hyoid bone and to the tongue. Its function is purely motor.

The Cerebellum. — Like the cerebrum, the cerebellum, or little brain, consists of two lateral hemispheres united by a central portion, called the *vermiform process,* situated beneath the medulla (Fig. 61). The cerebellum is situated in the posterior part of the cranium, beneath the cerebrum, and back of the medulla. It is separated from the cerebrum by a fold of the dura mater, called the *tentorium.*

It connects with the brain by three pairs of fibrous stalks, called peduncles, or crura (Fig. 62). They are known as the inferior, or lower, the middle, and the superior peduncles. The restiform bodies become prolonged from the medulla to form the inferior peduncles. From each of

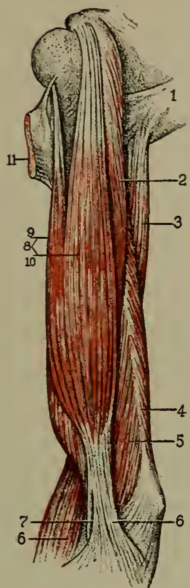
the hemispheres of the cerebellum the middle peduncles pass to form the transverse fibers of the Pons Varolii. The peduncles which connect the cerebellum with the cerebrum are the superior. They form the upper part of the lateral boundary of the fourth ventricle, and are connected by the valve of *Vieussens,* which is a continuation of the white center of the vermiform process, and which forms the anterior roof of the anterior part of the fourth ventricle.

The surface of the cerebellum presents quite a contrast with that of the cerebrum, the cerebellum being thrown in transverse furrows instead of convolutions. Like the cerebrum, it is composed of white and gray matter. The gray matter is on the exterior, forming its cortex. There is also a gray nucleus found near the center of each hemisphere, called the *corpus dentatum.* The white matter branches from the white center like a tree, forming what is called the arbor vitæ.

In its histological structure, the gray matter of the cerebellum presents, (*a*) an outer layer beneath the pia mater, composed of delicate fibers with small nerve cells and large neuroglia cells; (*b*) an inner, or granular, layer next to the white center, the layer being composed of closely packed granule cells; (*c*) a middle layer made of a single layer of large pear-shaped cells (the corpuscles of Purkinje) (Fig. 77), one thousandth to one eight-hundredth inch in diameter. Passing from the base of each of the cells, an axis-cylinder process goes to form one of the medullated fibers of the white matter, while from the opposite pole of the cell several processes pass outward into the outer layer. (Fig. 77.)

Function of the Cerebellum.— While the evidence from experiments seems to be somewhat conflicting, and causes doubt upon certain points, the burden of evidence is in favor of the following: —

1. That the function of the cerebellum is to secure the proper co-ordination of muscular movements, so that in such movements as standing, walking, talking, etc., the different muscles employed may each act at the right moment



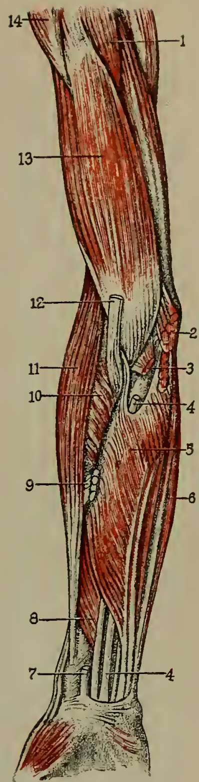


PLATE V.

FIG. 43.—MUSCLES OF ARM.

1 Latissimus dorsi. 2 Coraco-brachialis. 3. Triceps. 4. Intermuscular septum. 5. Brachialis. 6. Radiales. 7. Tendon of biceps. 8. Biceps. 9. Long head of biceps. 10. Short head of biceps. 11. Cut portion of pectoralis major.

FIG. 44.— MUSCLES OF ARM AND FOREARM.

1. Coraco-brachialis. 2. Cut end of flexor. 3. Cut end of pronator teres. 4. Median nerve. 5. Flexor sublimis digitorum. 6. Flexor carpi ulnaris. 7. Tendon of flexor carpi radialis. 8. Flexor longis pollicis. 9. Cut end of pronator teres. 10. Supinator. 11. Supinator longus. 12. Cut tendon of the biceps. 13. Brachialis. 14. Deltoid.

with due force. Other parts of the cerebrospinal system have a part in the work of co-ordination, especially the spinal cord. The efferent impulses from the various parts of the body stream into the nerve centers during muscular activity, and to harmonize and control these various impulses so that locomotion will be effected or some definite movement produced is the work of co-ordination, and may be effected by the reflex centers, but they are largely under the control of the cerebellum. The afferent impulses are of several kinds: (1) From muscular sense, (2) visual sensation, (3) the peculiar impulses that arise in the ampullary ends of the semicircular canals. These sensations do not always come into distinct consciousness. These various impulses may reach the cerebellum by one or the other of the peduncles, and may contribute to the regular association and action of muscular groups (see 2 and 3 below).

The evidences upon which we base the above conclusions are: (1) That the removal or injury of the cerebellum produces for some time, at least, a want of co-ordination; (2) that injury to one side causes inclination to fall toward the opposite side through failure of muscular power on the injured side; (3) that excitation of one side of the cerebellum gives rise to muscular contraction of the same side; (4) that dissection and degeneration show that the connection of the cerebellum hemisphere with the cerebral hemisphere is crossed; (5) that disease of the cerebellum very often leads to a staggering gait, with loss of muscular tone and power; (6) its removal does not affect the mental faculties.

2. It, at least in part, controls the power and tone of the muscles.

3. It has no share in the higher intellectual functions.

The Pons Varolii.— This lies above the medulla and between the hemispheres of the cerebrum, on transverse and longitudinal fibers intermingled with some gray matter. The transverse fibers are both deep and superficial, arising from the middle peduncles of the cerebrum. The

longitudinal fibers are arranged in bundles that pass down to the anterior pyramids of the medulla, where they decussate to form the motor tracts of the cord. There are other longitudinal fibers from the medulla and gray matter on the floor of the fourth ventricle which go to form the nuclei of the seventh, the sixth, and the fifth nerve. The motor fibers from the internal capsule to the facial nuclei decussate in the pons. This explains why an injury in the upper part of the pons affects the facial muscles of the opposite side, while injury in the lower part, after decussation occurs, paralyzes the muscles of the same side. The motor fibers that go to the limbs decussate in the medulla.

The Crura Cerebri (Fig. 62). — Arising from the upper border of the pons, they diverge and pass into the cerebral hemispheres. By section, each crus is found to consist of two parts separated by a dark gray substance, called *substantia nigra.* The anterior, or lower, part is called the *pes,* or *crusta,* and consists almost entirely of longitudinal fibers, which are continuous above with some in the internal capsule, and below with some in the pons that go to the anterior pyramids of the medulla. The dorsal, or upper part, of the crus is called the *tegmentum,* and consists of gray matter and fibers continuous with part of the pons and medulla, called the *formatio reticularis,* which is separated by transverse arched fibers and some gray matter. For the most part these fibers pass into the optic thalamus.

Corpora Quadrigemina. — These are four rounded prominences placed in pairs over the aqueduct of Sylvius and above the pons and crura. They are chiefly composed of gray matter with white fibers externally and a few internally. The white band which passes from the outer side of each of these prominences is called the arm, or *brachium,* and continues outward and forward. The bands from the posterior pair are lost beneath two prominences (the *internal geniculate bodies*) near the posterior part of the optic thalami (Fig. 66).

The bands from the upper pair pass into the bodies

known as the external geniculate bodies and the optic tract. The superior quadrigemina are only connected histologically with the optic tract, but they are related to them functionally as well, as is shown by their injury or destruction producing blindness. They appear to contain centers which have control over the contraction of the iris and over accommodation.

Optic Thalami. — These two masses are of oval shape, and project above into the lateral ventricles of the brain, their under surface resting on the tegmentum of the crus. The posterior and inner end of the thalamus projects over the arms of the corpora quadrigemina, and is known as the *pulvinar* (Fig. 66). Their inner sides form the lateral boundaries of the third ventricle. A prolongation of the tegmental part of the crura cerebri unite at their inner surface. On their outer side is the white matter of the internal capsule formed by fibers from the crusta of the crura that pass into the cerebral hemispheres without entering the optic thalami.

The optic thalami are composed of gray matter, with numerous nerve cells and white fibers which are mostly on the surface. They have connection with the posterior, or sensory, paths of the spinal cord through the tegmentum of the crura, and from their outer parts fibers pass onward to the cerebral hemispheres.

The Corpora Striata. — They are two in number, and each consists of two parts: (1) a pear-shaped part, the *caudate nucleus* projecting into the lateral ventricle of the same side in front of the optic thalamus, and (2) the part imbedded in the white substance of the cerebral hemispheres, called the *lenticular nucleus*. In a deep section of the brain between the two parts are seen the white fibers outside the internal capsule. The band of white fibers outside of the lenticular nucleus are those of the external capsule, and beyond the capsule is a thin *lamina* of gray matter, called the *claustrum,* which lies next to a lobe of the cerebrum in the fissure of Sylvius, called the central lobe, or *island of Reil.*

Each *corpus striatum* is made up of diverging white fibers mixed with gray matter, and in section it presents a striped appearance on account of its structure.

The Internal Capsule. — This broad band of white fibers lies between the lenticular nucleus of the *corpus striatum* on the outer side and the inner caudate nucleus and optic thalamus on the inner side. The fan-like expansion of its fibers into the hemisphere is called the *corona radiata.* For the most part the fibers of the internal capsule connect the cortex of the brain with the crusta and bulb below. In horizontal section the internal capsule shows a bend called the knee, or *genu;* the part in front of the genu is called the front limb, and the posterior part, the hind limb. The fibers of the capsule curve away in many directions to various parts of the cerebral surface.

In the internal capsule are found: —

1. *The Fibers of the Pyramidal Tract* which can be traced from their origin in the motor areas of the cerebral cortex, around the fissure of Rolando, through the middle third of the internal capsule into the crusta of the crus cerebri, thence to the pons and the anterior pyramids of the medulla. Most of the fibers decussate at the lower part of the medulla as they pass into the spinal cord, where they form the crossed pyramidal tracts. Some of the fibers of this tract, however, pass to nuclei of the cranial motor nerves in the pons and medulla. The uncrossed fibers form the direct pyramidal tract.

2. *The fronto-cortical fibers* which originate in the frontal convolutions anterior to the motor area, and pass down in the anterior third of the capsule through the crusta into the pons, where they appear to terminate in the gray matter.

3. *The temporo-occipital fibers* which take origin in the temporal and occipital regions of the cortex, and passing through the posterior third of the capsule, terminate in the outer part of the pons.

In addition to the above-mentioned tracts, the internal

capsule contains fibers from the *nucleus caudatus* of the corpus striatum that terminate in the pons, and also fibers from various parts of the cortex that terminate in the gray matter of the optic thalami. There seems to be little doubt that the pyramidal tract of the internal capsule is concerned in conveying voluntary motor impulses from the cerebral cortex to the muscles.

The tract seems to be well marked, as is shown by the degeneration process, and is one of descending degeneration, having its trophic center in the cells of the gray matter of the cortex. As the fibers decussate, their injury produces paralysis of the muscles of the opposite side of the body and face. A paralysis of but one side is called hemiplegia. The posterior part of the hind limb of the internal capsule contains numerous sensory fibers connected with the opposite side of the body, and for this reason distribution of the internal capsule produces a loss of both motion and sensation.

Cerebrum.— By the cerebrum is meant the two large oval masses of gray and white matter that overlap all the rest of the brain. The term cerebrum usually includes all of the brain in front of the cerebellum and pons, including not only the cerebral hemispheres, the corpora striata, and optic thalami, but the corpora quadrigemina and the crura cerebri as well. As we have seen, these two masses are separated by the great longitudinal fissure (*median*) (Fig. 63), except at about the middle of half of their extent, where they are united at the depth of about an inch by the transverse fibers of the corpus callosum (Figs. 61 and 65). The surface of each hemisphere is very uneven, being thrown into numerous folds, called *convolutions*, or *gyri*, separated by depressions, called *sulci*. This folding tends to increase the superficial area, and increases the amount of the gray matter. The deeper depression or grooves are called fissures, and divide the surface of each hemisphere into five parts, called lobes, while others separate the convolutions of each lobe from one another.

The more important fissures are: The *fissure of Rolando* (Fig. 83), which begins near the middle of the longitudinal fissure at the top (*vertex*), and passes on the outer surface of each hemisphere obliquely downward and forward toward the great fissure of Sylvius; the *fissure of Sylvius,* which begins on the under surface of the hemisphere, and passes upward and backward for two thirds of the distance from before backward; a long fissure (*calloso-marginal fissure*), beginning below on the inner part of the longitudinal fissure (*mesial surface*) and running backward for some distance above the corpus callosum and ending behind the fissure of Rolando.

The more important lobes are *the frontal lobe,* which lies in front of the fissure of Rolando and above the fissure of Sylvius. By smaller fissures it is divided into four main convolutions, the superior, middle, inferior, and the ascending frontal convolution (Fig. 76); *the parietal lobe,* which is bounded in front by the fissure of Rolando and below by part of the fissure of Sylvius. Its divisions are *ascending parietal convolution* situated around the end of the fissure of Sylvius and the *angular convolution* around the end of the temporal fissure; *the temporo-sphenoidal lobe,* which lies below the horizontal part of the fissure of Sylvius, and presents three parallel convolutions, called the *first,* or *superior temporal, second,* or *middle temporal,* and *third,* or *inferior temporal. The occipital lobe,* which is of small size, lies at the posterior end of the cerebrum, separated from the parietal lobe by the perpendicular parieto-occipital fissure. It has three convolutions, a superior, a middle, and an inferior. The *central lobe,* or island of Reil, concealed within the fissure of Sylvius, and may be seen by pulling apart the edges of the fissure. The *gyrus marginalis* lies between the surface of the hemisphere and the calloso-marginal fissure. The *gyrus fornicatus* lies between the calloso-marginal fissure and the corpus callosum. The *gyrus uncinatus* is located at the end of the temporo-sphenoidal lobe. The *gyrus hippocampi,* which is formed from the pos-

terior end of the gyrus fornicatus, passes downward forward. The *quadrate lobes* are situated at the posterior end of the marginal convolution and parieto-occipital fissure, and just beneath this lobe lies the *cuneate lobe*.

Structure of the Cerebrum.—From our dissections we have found it to consist of white and gray matter; the white being mostly in the middle of the hemisphere and extending into the convolutions, while the gray forms the outer part, or cortex, making a layer from one-sixth to one-fourth inch deep.

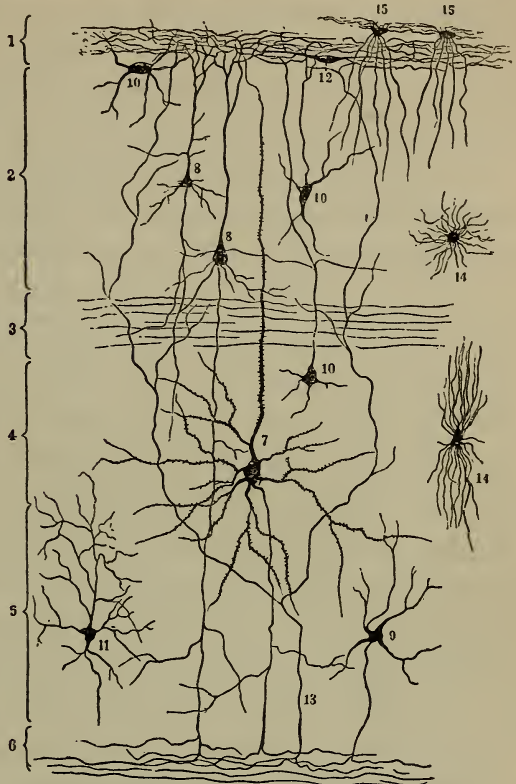


FIG. 77.—PRINCIPAL CONSTITUENT OF CORTEX OF THE BRAIN.

1. Stratum zonale tangential fiber. 2. Small pyramidal cells. 3. The white band striæ. 4. The large pyramidal cell layer. 5. The layer of small irregular cells. 6. Lower limiting fibrous layer. 7. Large pyramidal, with three long dendrites and spiny branches; the dendrites forming the fibrous layer above. 8. A small pyramidal cell. 9. Irregular cell, sending dendrites to lower limiting layer. 10. Small cells whose axis-cylinders go to make the outer layer. 11. Cell with many-branched axis-cylinders. 12. Fusiform cells of the banded layer. 13. The far-reaching fibers. 14. Stellate cells.

The white matter consists of medullated nerve fibers arranged in bundles and supported by neuroglia. These fibers vary in size in different parts of the brain, but for the most part are smaller. The gray matter of the convoluted surface is arranged in a continuous layer, but divided into strata by

light lines. The appearance to the naked eye of a section of the gray matter of the convolutions is shown in Fig. 66. It consists of a thin coating of white matter, best developed on the convolutions within the great median fissure; a layer of gray or reddish-gray matter; a thin, whitish layer; a yellowish-gray stratum, sometimes showing a thin, whitish line; and the central white matter of the convolutions.

The microscopic structure of the gray matter (Fig. 77) is complex, and presents five layers: (1) a superficial layer, with a few small ganglionic cells and an abundance of neuroglia; (2) a layer of small pyramidal cells; (3) a thick layer of pyramidal cells, each having a process passing upward toward the surface from the pointed apex process, passing off laterally, and a process from the center of the base, which becomes continuous with axis-cylinder of a nerve fiber. The pyramidal cells become larger in the lower part of the layer, and bundles of nerves are seen passing downward from this layer into white matter; (4) a layer of granules and small, irregular nerve cells; (5) a layer of fusiform cells running for the greater part parallel to the surface. The relation of the different layers varies in the different regions of the brain. In the motor area the large pyramidal cells are well developed; in the occipital region the granular is best developed; while the pyramidal cells are few in the Sylvian fissure, the fusiform cells are best developed of any part of the body.

The axis-cylinder process of the pyramidal cells passes into the medullary center, to form either associated fibers connecting other parts of the same side, or commissural fibers through the corpus callosum, to the opposite hemisphere or projecting fibers, to the corpus striatum or optic thalamus, or by way of the internal capsule to the crura, pons, medulla, and spinal cord.

Functions of the Cerebrum.— Our present knowledge of the functions of the cerebrum has been derived from various sources, the more important of which are: (1) the development of the cerebrum in the different races of men,— in the more intelligent the cerebrum is larger and more deeply con-

voluted; (2) from the comparison of the cerebrum of different vertebrate animals, it is observed that as animals increase in intelligence, the cerebrum increases in size, and the depth and number of its convolutions, and in its size in proportion to other parts of the brain and weight of the body of the animal; (3) its imperfect development in idiots and imbecile persons; (4) the effect of injury of all or part of the cerebrum by disease or violence, producing loss of certain powers of the mind and body, or entirely destroying consciousness; (5) by removal, producing entire loss of intelligence, as shown by experiments on the lower animals.

If the cerebral hemispheres be removed from a frog, while still able to perform many complex movements when properly stimulated, it has lost all power of spontaneous movement. It can sit in a natural position, breathing quietly; but if undisturbed, remains motionless for an indefinite time. If placed on a board, and the board be lifted, it will crawl up to a position of equilibrium; if pinched, it will jump away, avoiding any obstacle in its way; if placed in water, it will swim until an object is put before it to rest on. It manifests no hunger, makes no effort to secure food, and shows no sign of fear. How different these reflex movements from those of the frog with its entire brain intact. The animal seems to be a mere machine.

If a pigeon be deprived of its cerebral hemispheres, it behaves very much in the same way. Undisturbed, it remains still, though by the proper stimulus it can be made to fly. It will starve to death on a heap of corn, though it begins to eat on holding its beak in it. It is, however, devoid of emotional and intelligent movements.

On the higher animals but few observations have been made, as it is difficult to remove the cerebral hemisphere without producing fatal shock. A dog deprived of the cerebral hemispheres, as described by Goltz, after recovering from the shock of the surgical operation, walked and moved about in a normal manner, though often wandering restlessly. It slept at night, but any loud noise awoke it. A sudden

light caused it to close its eyes, and an injury to one foot caused it to limp on three legs, showing that co-ordination both of simple and complex movements was not impaired.

It at first would not eat, but had to be fed; but after some months it would help itself on being started. It seemed to be entirely wanting in the higher intellectual faculties. It paid no notice to the barking of other dogs, or to the kind treatment of its master. While having the power of complicated movements, of taking food, and the sensation of taste and sight, it had no memory or other power that indicated intelligence.

From these experiments, and clinical experience, it would seem that while the lower centers may receive afferent impulses, and give off efferent stimuli, resulting in complex movements, increasing in degree and importance as we pass from the spinal cord to the medulla and lower parts of the brain, the cerebrum alone has the power to convert afferent, or sensory, impulses into mental impressions that give rise to conscious perception and leave vestiges, which, as recollected ideas, form the basis of intellectual activity; and in the cortex alone can there issue those impulses known as voluntary, or efforts of the will. We may therefore conclude that the cerebrum is (1) the seat of the mind; its attribute, feeling, intellect, and the will; (2) that it exercises inhibitory or controlling power over the lower centers; (3) with its special areas to preside over the voluntary movements, those of speech, and as the centers of the special senses.

If one of the cerebral hemispheres becomes injured, the power of mind may be carried on by the other hemisphere, but, as we have seen, there would be a complete paralysis of the parts of the body to which the nerves from the affected parts go.

As we have found, there are certain reflex acts which are natural or inherent in the spinal cord. By the help of the brain, however, new systems of reflex paths may be set up in the nervous structures, and we may become possessed of many acquired or artificial reflex acts,— those actions which at first

require close attention and continuous effort of the will become by repetition so ingrained in the nervous structure that a single sensation or a single impulse from the brain may set the whole train in action, and thus may be performed unconsciously. Thus many acts of attention and will become reflex. Our voluntary and reflex acts shade into each other, a series being often connected by one or both kinds. In a strictly voluntary act there must be the guidance of an idea, perception, and volition; but in acts of habit, conscious effort is not required beyond giving an impulse that starts a series. A habit has been defined as a reflex discharge from some nervous center, the most complex being, Professor James says, " nothing but connected discharges in the nerve centers due to the presence there of systems of reflex paths so organized as to wake each other up successively, the impression produced by one muscular contraction serving as a stimulus to provoke the next, until a final impression inhibits and closes the whole chain."

Cerebral Localization.— It was formerly thought that the brain acted as a unit, and therefore injury to any part of the cerebrum would produce a loss of mind and instant death, but of late years we have come to look upon the brain as not only complex in structure, but localized in function; i. e., that the different parts of the cerebral cortex have different functions. There are a number of things which give support to this view, among the most important of which may be mentioned: (1) The removal of the cerebrum of a living animal, layer by layer, and carefully noting the effect; (2) stimulation by means of electricity of certain areas of the cerebrum, and noting the effect, that while one area stimulated the contraction of a certain set of muscles, another area would give rise to the contraction of an entirely different set of muscles; (3) the effect of disease of different parts of the cerebrum in producing paralysis differing in degree and kind, some affecting vision, some affecting motion of the lower limbs, some affecting motion of the upper limbs; (5) by the study of the degeneration of the nerve fibers; (6) from embryological observation.

The more important motor areas are situated in the convolutions around the fissure of Rolando. They are: (1) The outer surface of the upper part is concerned with the movements of the leg; (2) the middle with the movements of the arm; (3) the lower part with the movements of the face and mouth, and on the inner surface of the median associated with the head, arm, trunk, and leg; (4) the speech area in the third frontal convolution, a lesion of which produces loss of power of speech, or *motor aphasia,* as it is called; (5) sensory area in the posterior part of the first temporal convolution. The distribution of these various areas may be learned by a study of Fig. 78.

It should be remembered that these areas are not distinct, but often overlap. These areas do not have the power of originating efferent impulse, but they must be first awakened by sensory impulses. Cerebral localization is of great aid to the physician in locating the seat of a disease of the cerebrum.

The Sympathetic System.—The sympathetic system consists (1) of a double chain of ganglia and fibers extending from the cranium to the pelvis along each side of the vertebral column, and from which branches are distributed both to the cerebrospinal system and to other parts of the sympathetic system. With this chain may be included the small ganglia in connection with those branches of the fifth cerebral nerve, which are distributed in the region of the organs of special sense, as the *ophthalmic, optic, sphenopalatine,* and *submaxillary ganglia;* (2) various ganglia and plexuses of nerve fibers, which give off branches to the thoracic and abdominal viscera, the nerves to important plexuses of which are the cardiac, solar, and hypogastric (see Figs. 79 and 80). To the plexuses, fibers pass from the prevertebral chain of ganglia, also from the cerebrospinal nerves; (3) various ganglia, and plexuses in the substance of the viscera, as in the stomach, intestines, and urinary bladder. These are of small size, most of them being microscopic. They have free communication with other parts of the sympathetic system, and also to some extent with the cerebrospinal; (4) by some the gan-

glia on the posterior roots of the spinal nerves on the glosso-pharyngeal and vagus and the sensory root of the fifth cerebral nerve (Gasserian ganglion) are considered as sympathetic nerve structures.

From the researches of Gaskell we may classify the sympathetic ganglia into: (1) The main sympathetic chain, consisting of twenty-four pairs, extending from above downward, beginning in the cervical region in a single ganglion and terminating below in a single ganglion, and constituting a connected chain lying upon the bodies of the vertebræ. This chain is called the *lateral, or vertebral, ganglia;* (2) a more or less distinct chain in front of the vertebræ, consisting of the semilunar inferior mesenteric and solar plexuses called the *collateral ganglia;* (3) the ganglia which are situated in the organs and tissues themselves, called the *terminal ganglia;* (4) the ganglia of the posterior roots of the spinal cord.

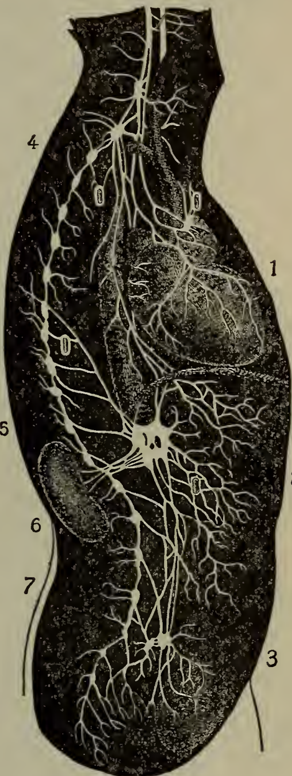


FIG. 79.—DIAGRAM OF TRUNK, SHOWING PRINCIPAL SYMPATHETIC PLEXUSES.

1. Cardiac plexus. 2. Solar plexus. 3. Hypogastric plexus. 4. Inferior cervical ganglia. 5. Dorsal ganglia. 6. Lumbar ganglia. 7. Sacral ganglia.

The connection of these various parts is as follows: The visceral branch, or ramus, communications (Fig. 57) of each spinal nerve pass first into the lateral chain, from which branches (*rami efferentes*) pass into the collateral ganglia, and from these again are given off branches which go to the organs to end in terminal ganglia. In the thoracic regions the *rami communicantes* are composed of two parts, white and gray. The white can be traced backward into both spinal

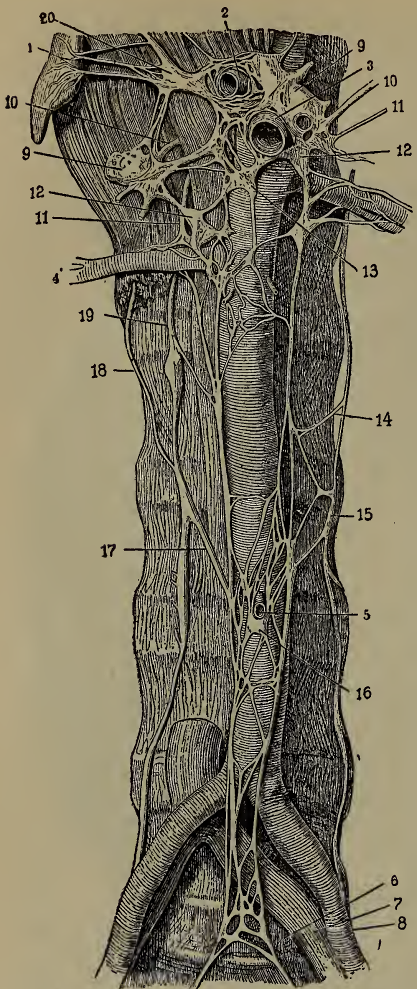


FIG. 80. — SOLAR AND HYPOGASTRIC PLEXUSES WITH THEIR CONNECTIONS.
1. Suprarenal capsule. 2. Hepatic artery. 3. Superior mesenteric artery. 4. Renal artery. 5. Inferior mesenteric artery. 6. Sacrovertebral angle. 7. Common iliac vein. 8. Common iliac artery. 9. Semilunar or cœliac ganglion. 10. Greater splanchnic nerve. 11. Lesser splanchnic nerve. 12. Renal ganglion. 13. Superior mesenteric ganglion. 14. Branch to aortic plexus. 15. Gangliated cord of sympathetic. 16. Inferior mesenteric ganglion. 17. Branch to aortic plexus. 18. Communicating branch. 19. Gangliated cord. 20. Phrenic ganglion. 9, 12, and 20 go to make up the solar plexus.

nerve roots of their cornua, and in the other direction partly into the lateral sympathetic chain and partly into the great splanchnic nerves, and so into the collateral ganglia, without entering the lateral chain at all. The upper white branch (*ramus*), however, proceeds upward, and joins the superior cervical ganglia instead of passing downward into the splanchnics. There are other branches which go downward to the lumbar and sacral plexuses.

The gray branch (ramus) of all the spinal nerves is the only apparent representative of the visceral branches in the regions above the second thoracic nerve root and below the second lumbar nerve root, with the exception of the roots of the second and third sacral nerves, which also have white rami, and are made up of non-medullated fibers, and pass from the ganglia to be dis-

tributed chiefly to the spinal column, to the spinal membranes, and to the spinal nerve roots themselves. For this reason we may consider the white rami as the visceral branches proper.

The fibers of the white medullated visceral nerves are distinguished by the fineness of their fibers, being about one fourth the diameter of ordinary medullated fibers (1.8μ to 2.7μ, instead of 14.4μ to 19μ). These white fibers are found principally in the spinal nerve roots of the thoracic regions, but they are also found in the second and third sacral nerves, forming the *nervi erigentes,* which pass directly to the hypogastric plexuses, from which branches pass upward into the inferior mesenteric ganglia, and downward to the bladder, rectum, and generative organs. These differ from the visceral branches of the thoracic region in that they do not communicate with the lateral ganglia.

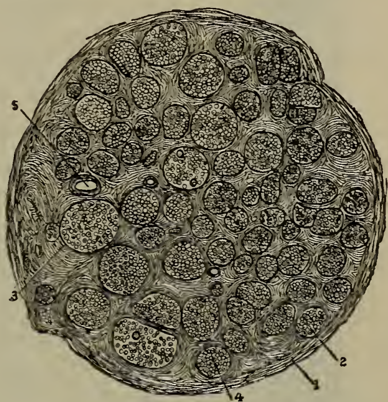


FIG. 81.—SECTION OF PNEUMOGASTRIC NERVE, HUMAN. (Highly magnified.)
1. Sheath of nerve (epineurium). 2. A fasciculus of nerve fibers. 3. Sheath of fasciculus (perineurium). 4. Nerve fibers. What appears to be cells with nuclei are the cut end of the nerve fibers; the outer ring being the nerve fiber sheath (neurilemma), the lighter space the medullary sheath, and what appears to be the nucleus, the axis-cylinder. (Brinckley, C. W. B.)

The efferent nerve fibers of the sympathetic system supply (1) the muscles of the vascular system, and in their function are vasoconstrictor and cardiac augmentor, vasodilator, and cardiac inhibitor; (2) visceral muscles, giving to them both vasomotor and vasoinhibitor fibers; (3) the secretory gland cells. These will be considered more at length when we study the organs to which they are distributed.

Ganglia, Their Structure and Function.—The sympathetic ganglia consist of the nerve fibers traversing them; the nerve fibers which originate in them; and the nerve or gan-

glion corpuscle, which gives origin to the fibers and other corpuscles that appear free. In the sympathetic ganglia of some of the nerves, cells of a very complicated structure are found.

The chief functions of the main sympathetic ganglia are, (1) to effect the conversion of medullated into non-medullated fibers; (2) to give a nutritive influence (trophic) over the nerves which pass from them to the periphery; (3) to increase the number of fibers at the same time that they cause the removal of the medulla. It was formerly thought that ganglia possessed the power of reflex action similar to that of the spinal cord, but this is now considered doubtful.

FIG. 82 A.—MEDULLATED NERVE FIBER (blackened by osmic acid).
Black central portion axis-cylinder. Schwann's sheath or neurilemma. The cell-like body (nerve corpuscle) lies between the neurilemma and the second coat of the nerve (white substance of Schwann, medullary sheath or myelin).

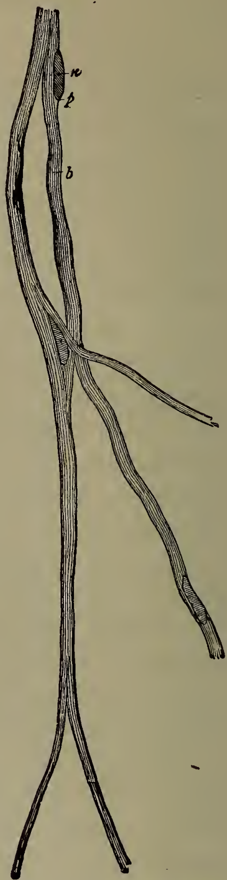


FIG. 82 B.—NON-MEDULLATED FIBER (Remak's fiber).
Fiber from vagus of dog. *b.* Fibrils. *n.* Nucleus. *p.* Protoplasm surrounding it.

The Structure of Nervous Tissue.—It is composed of the white and the gray matter. The gray matter is found in the cortex of the brain, in masses, in the substance of the white matter of the brain, in the ventricles, and in certain bodies at the base of the brain, in the interior of the spinal cord, and in the ganglia.

The white matter is found on the interior part of the brain, connecting the various gray masses on the exterior part of the spinal cord and in the nerves. The fibers of the white matter are bound into large or smaller thread-like masses, called *nerves,* which bring into relation the nerve centers with the rest of the body. The larger nerves are somewhat complex in structure. The sheath which invests the nerve is called the *epineurium,* the part which surrounds the bundles (*funiculi*) which make up the nerve is called *perineurium* (Fig. 81), and the membrane which passes between the fibers of the bundle (*funiculus*), the *endoneurium.*

The separate threads which compose the nerve are called fibers. They vary greatly in size; the largest are found in the spinal nerves, and are from 14.4μ to 19μ in diameter. There are nerves mixed with these which measure only 1.8μ to 3.6μ. These small fibers are found principally in the visceral nerves; they pass to sympathetic ganglia, where they leave as non-medullated fibers, and are distributed to the involuntary muscles.

When fresh, the nerve fiber appears very simple, but on standing, or by means of special reagents, it is shown to be complex. The nerve fibers may be classed into two varieties: the *medullated,* or white, and the *non-medullated* fibers (*fibers of Remak*). The medullated fibers (Fig. 82 A) consist of a central core, the continuation of the process from a nerve cell, and the essential part of the nerve, called the *axis-cylinder,* which is gray and granular; outside this is a sheath of white color, fatty in nature, which stains black with osmic acid, known as the *medullary sheath* of white substance of Schwann; and investing the medullary sheath, is a thin homogeneous membrane of elastic nature, called the primitive sheath, or *neurilemma.* The medullary sheath is constricted at somewhat regular intervals, known as the *nodes of Ranvier,* and the intervening space between the nodes as the internode. The axis-cylinder is not simple, as it appears at first, but it is made of exceedingly small fibers, which stain readily with gold chloride.

The non-medullated fibers (Fig. 82B) have no medullary portion or white substance of Schwann, and do not present, therefore, the double contour of the medullated fibers; they are unaffected by osmic acid.

The covering of the axis-cylinder is a nucleated, fibrillated sheath. These fibers branch frequently. The medullated fibers are found in the white matter and in the nerves having their origin in the brain and spinal cord, the non-medullated in the sympathetic system, but a few are found in the spinal nerves, mixed with the medullated fibers.

FIG. 83.—NERVE CELLS FROM SPINAL CORD OF CALF.
1. Dendron. 2. Nucleus. 3. Neuroglia. 5. Body of cells. 7. Nucleolus. 6. Dendrites. (Brinckley, C. W. B.)

How Nerves End.—This will be considered under the respective tissues to which they are distributed.

Structure of Gray Matter.—The structure of the gray matter differs greatly in the various parts of the nervous system, the cells having different form, shape, and structure as they become specialized in their function. As a rule, nerve cells have large, round nuclei, in which are one or more nucleoli. The protoplasm of the cell is granular, but may be striated or reticulated. Some contain a yellowish-brown pigment. Some nerve cells are small, generally spherical or ovoid, and regular in outline, and inclosed in a nucleated sheath. These are found principally in the sympathetic ganglia. There are other cells which are large, caudate or stellate (Fig. 83), and having one, two, or more processes (poles), and are called unipolar, bipolar, or multipolar, according to the number of poles they have.

These processes often divide and subdivide, breaking up in some cases into a fine arborescence. The processes appear tubular, and filled with the same kind of granular material as the cell. If we are to take the conclusion of recent investigation, these do not anastomose, as was formerly thought, but end, as stated before, in fine arborescence, which interlace, but do not join. There is, therefore, no continuous chain between cell and cell (Fig. 84).

Old authors speak of the nervous system being made up of two distinct substances, the white matter (nerve fibers) and the gray matter (nerve cells). Better histological methods have enabled us to determine nearer the true nature of the nervous system, and the modern view is that it is composed of one element, called the neuron (Figs. 84 and 85), or nerve unit, which is imbedded in and supported by a substance called neuroglia. The neuron consists of a cell body, a number of branching processes, called dendrites, and a long process, neuraxis, which becomes the nerve fiber. A nerve center is simply an aggregation of neurons arranged in different ways in the different parts of the nervous system.

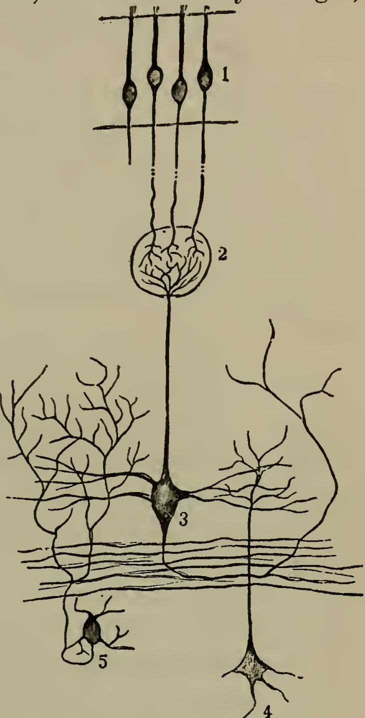


FIG. 84.—THE OLFACTORY BULB. (Diagram of structure.)
1. Nasal epithelium. 2. Glomerulus of olfactory bulb. 3. Mitral cells. 4. Central fibers.

It was discovered by Golgi that the individual nerve fiber of the central nervous system gives off in its course branches, which pass off from it at right angles for a short distance, and then turn back and run in various directions. These

branches are called *collaterals,* which end in fine, brush-like bodies, called *brushes,* or in little bulbous swellings, which come in close contact with some nerve cell. The collaterals are more numerous in nerve centers.

Neuroglia. — It was formerly thought that neuroglia[1] was a form of connective tissue, inasmuch as it performs functions similar to that of connective tissue, but its origin excludes this idea, as it is derived from the epiblast, the same embryonic layer from which the nervous system is derived. The tissue is made up of numerous cells, from which are given off numerous branches, some of which may again branch to form a fine network. The arrangement and form of the neuroglia cell differ in different parts of the nervous system, according to the arrangement of the nervous structures it supports.

HYGIENE OF THE NERVOUS SYSTEM.

Need of Exercise. — The nerves, like the muscles, need exercise. It is a biological law that the proper exercise of an organ results in its development and strength, while its disuse brings loss of power and degeneration (*atrophy*). Would we have strong nerves, a vigorous and active brain, we must give them constant and judicious exercise. Spasmodic efforts will not secure this; as with the muscles best results are only secured by persistent and regular exercise.

The increased power and size of the various parts of the nervous system is due to the same cause as in the muscles, a better supply of pure blood, giving a greater store of fresh material for the discharge of energy, and more effective removal of the waste products. This gives the system great power for its general function, and also a large reserve force to overcome disease, and to meet any extra demands that may be made upon it.

[1] *Velocity of Nervous Impulse.*—The velocity of nerve impulse is influenced by various conditions, some of the more important of which are the following: (1) Cold lessens its velocity, and also temperature, 25° C.; (2) electricity, *anelectrotonus* lessens, while *cathelectrotonus* increases; (3) the length of the nerve; (4) nature and strength of the stimulus.

The average velocity in the frog is 27 meters, and in man it has been estimated from 30 to 60 meters per second.

Fatigue of Nerve Cells.— There is a limit to the power and activity of the cells of the various centers and parts of the nervous system. If the exercise or stimulation is too prolonged, exhaustion of the cells may result, and to every cell there is a limit of its power of restoration after exercise. In extreme fatigue it is the nerve cells and not the muscles which succumb to exhaustion.

Under influence of stimuli, the nerve cells become shrunken and irregular in outline, while the nuclei of the cell and of the inclosing cell wall become smaller. These regain their normal size and shape after proper rest, or after refreshing sleep. There is marked difference in the appearance and size of the nerve cells as we awaken in the morning, refreshed by the night's sleep, and as we retire in the evening, fatigued by the heavy labors of the day. These differences in the condition of the cells may be readily noticed by examination with a microscope.

Sleep.— While we do not fully understand the mystery of sleep, yet experiment and our experiences show us its need and importance. The respiration and circulation become slower, the activities of the body lessened, the constant storm of afferent sensation that has been battering at the nerve centers, and great nervous stimuli which they call forth, cease to a large degree. The nervous activities are restricted to the reflex centers, and in very profound sleep to the automatic centers, thus relieving the cerebrum and the higher centers. Sleep is nature's restorative.

The higher the organism and the greater the development of the nervous system, the greater the need of sleep.

The Amount of Sleep.— It takes some time for the cells to regain their normal condition and size after they have been subjected to several hours of activity. Our sleep, in order to be refreshing, must be uninterrupted for several hours. There will be a very close relation between the activity of the individual and the amount of sleep that an individual takes. Great activity demands a corresponding amount of sleep. Most adults should take at least eight hours of sound

sleep. Children require more than adults; the aged less. The amount required varies also with the habit and individual peculiarities.

Sleeplessness.— Normally, the waste products which collect in the blood of the brain from the activity of the nerve cell give a sense of fatigue, which begets sleep; but their presence may excite cerebral activity and produce a sense of wakefulness. Undue blood tension in the brain may produce a similar effect. Overwork or undue excitement may bring about these conditions. If sleeplessness (*insomnia*) continues for sometime, and repeats itself night after night, it should receive immediate attention. If due to overwork or overexcitement of the nerve centers, the cause should be removed.

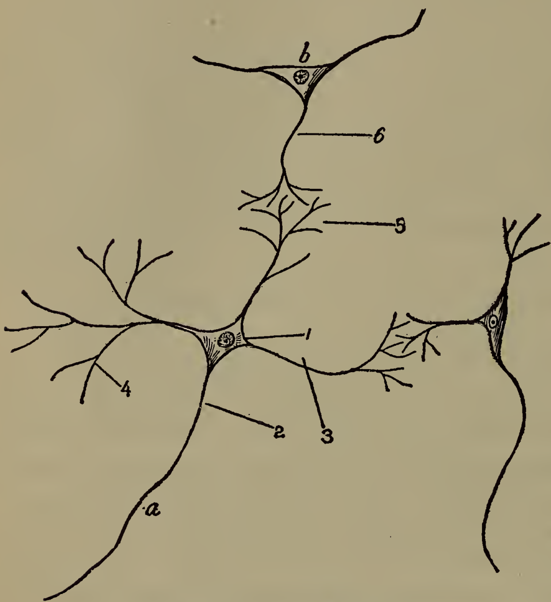


FIG. 85.—DIAGRAM OF NEURONS.

1. Nerve cell. 2. Neuraxon. 3. Dendron. 4, Dendrite. 5. Arborescence of dendrites. (The neuron is made up of 1, 2, 3, 4, and 5.) 6. Dendron of another neuron, *b*, with its branches interweaving with those of *a*. (Brinckley.)

There are a number of medicines (*hypnotics*) that have the power of producing sleep, but these should not be given except under the direction of a physician. Sleep may often be produced by very simple means. The first thing is to relieve the mind of all care and excitement. The blood pressure of the brain must be lessened. The reclining position,

quiet and darkness, are favorable to sleep. A foot bath, rubbing the lower limbs, a lunch of light digestible food, or a warm bath followed by vigorous rubbing, and gentle exercise, will reduce the blood tension of the brain by calling the blood to other parts of the body, thus bringing about sound sleep.

Nutrition of the Nervous System.— While the nervous system regulates all motion, controls all vital process, yet it is dependent upon the very action which it itself excites. While the salivary gland cannot secrete without the proper nervous stimulus, the nerve center is dependent upon the proper action of the salivary gland for its proper growth; so is it with the other organs. Like the other organs of the body, the activity, strength, and development of the nervous system depend upon pure blood to give it material for growth and discharge of nerve energy, and to carry away the waste products of its activities.

Good blood is dependent upon a proper supply of oxygen and removal of the carbon dioxide, and this requires proper action of the respiratory organs. The food material must be prepared by the alimentary tract, and to get the most from our food it must be thoroughly digested. Not only must the blood be pure, and laden with energy-giving materials, but its flow must be regulated to secure the proper blood supply and pressure. This last condition is dependent upon the proper action of the heart and the blood vessels. How important it is that these processes be well performed; that the nervous system, which is dependent upon them, be properly nourished.

Many of the so-called cases of nervous exhaustion (*neurasthenia*) are not really so much a disease (i. e., an actual degeneration or structural change in nervous matter) of the nerve tissues, as a lack of their proper nutrition, resulting from sluggish circulation, poor blood, and imperfect digestion. The remedy is to be sought in most cases not in sedatives or stimulants, but in a change of habit, judicious exercise, proper food, and an improved digestion.

True nervous exhaustion is comparatively rare, and is a very serious condition, and demands the most skillful treatment.

Habit.— The repetition of an act renders its performance easier. This is due to the fact that when afferent impulses and efferent stimuli have passed over a certain path, their course becomes fixed. Acts which required our attention become reflex; i. e., can be carried on without our attention. When the course of the action has thus become fixed, we call it a *habit*. Many of our acts, which would demand consciousness, become reflex, relieving the higher centers; as the cerebrum is relieved from the care of these movements, it is free to take charge of the higher, or intellectual, activities. In playing a difficult piece, the musician directs his attention to the interpretation of the melody, the harmony, and expression of the piece, leaving to the reflex centers the mechanical execution, and through the training he has received, the fingers strike the right notes, in the right time, and with the right force, without his thought or attention. Had his attention been required for the mechanical execution, what note to strike, how long, and with what force, the skillful rendering of the piece would have been impossible. Skill is thus possible, where otherwise our movements would be restricted to the simple ones.

The law of habit applies as well to our moral being as to our physical. It has been said that character is a bundle of habits, and that we are what we make ourselves by our acts. If we engage in right acts until adult age, we will form habits of right doing, and our tendencies will be for the right; if we engage in wrongdoing, bad habits will be formed, and our tendencies will be to the wrong.

Repeated acts of kindness, love, truthfulness, honesty, and industry in youth become habits, and the doing of them becomes a joy. It is just as true that continued acts of unkindness, indolence, falsehood, and dishonesty produce habits that bring misery.

If we would have noble characters, we must accustom our-

selves to the doing of noble deeds, the thinking of noble thoughts, the loving of noble things. Habits, when once formed, are difficult to break, and often when persons who form bad habits desire to do right, they find themselves chained to evil by their habits. Good habits are equally as strong. Youth is the habit-forming period of life; what we are at twenty we are likely to be at forty. One of the strongest safeguards against evil is youth and manhood spent in rightdoing. Habits not only impress the individual, but as well his descendants, and may persist through several generations.

Every organism is under the influence of *heredity* and *environment*. By the former we have certain temperaments, appetites, and tendencies, some of which impel to noble action, while others, if followed, tend to degrade us.

The environment, if favorable, tends to the improvement of the organism, or if unfavorable, to its injury or destruction.

The effects of heredity may, to a large degree, be overcome by proper environments. We cannot prevent our hereditary tendencies and physical inclinations, but we may overcome them by putting ourselves under the influence of the best environments. Crime has a *physiological* as well as a *moral* basis. The scanty food, the unwholesome air, the poorly lighted apartment, the evil associations, have much to do with the production of crime. Alcoholism is not only a crime, but a disease as well.

In no system of the body are these influences more marked than in the nervous system, and hence the importance of wholesome food, well-ventilated and well-lighted rooms, judicious exercises, cheerful and ennobling surroundings.

Effects of Alcohol on the Nervous System.[1] — Evil as the effects of alcohol on the other systems of the body may be,

---

[1] The action of alcohol on the nervous system depends on the dose, its size, and the frequency of its repetition. In a moderate dose, the whole nervous system is stimulated to a slight extent, probably directly, but chiefly by the secondary effect due to the vascular dilation and cardiac stimulation. In this stage the higher functions are most affected. If the dose be large, the stage of stimu-

they are not to be compared in magnitude to the injury to the nervous system. Many of the injuries of the other organs of the body, due to the use of alcohol, are due in many cases to its effect on the nervous system.

In moderate doses, alcohol [1] acts as a cerebral stimulant; in large ones, a depressant. The former, if kept up, results in nervous exhaustion in proportion to their frequency and amount.[2] The large dose may bring immediate unconsciousness and depression, and if the dose is very large, immediate death.

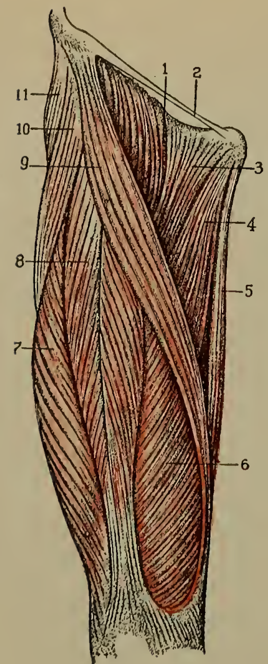
A person *intoxicated is truly poisoned* (as the word expresses). The abnormal pulse, flushed face, the respiration, the lower temperature, the staggering walk, or the unconsciousness, show this. Alcohol also affects the motor and sensory areas of the cerebrum, as well as the centers of co-ordination, as is seen in the bewildered vision, the imperfect speech, and the staggering gait. It affects the automatic and reflex centers of the medulla, as shown in the flushed blood vessels, the quickened pulse and respiration. This affects the blood vessels of the brain, as well as the other parts of the body, and may result by continued use in chronic congestion, putting in danger the life of the person by sudden death from apoplexy. It also affects the metabolism and the nutri-

---

lation soon passes into one of depression as before, the higher function being affected descending from the higher to lower centers, the lower being the last to yield to its depressing effects. The loss of the powers would be in the following order: judgment, imagination, control of the emotions, control of speech, control of delicate muscular activity, as writing, the power to walk, reflex centers of the cord, as those of micturition, the respiratory centers, and lastly, the heart. It should be observed that the order of depression is the order of stimulation; i. e., the first to be stimulated is the first to be depressed; the one most easily stimulated, the one easiest depressed; the one most difficult to stimulate is the one last to be paralyzed. In moderate dose alcohol acts as a stimulant; in larger dose as hypnotic, or narcotic.

[1] In action of alcohol, opium, chloral, and cocaine, we have two very important laws illustrated: 1. Drugs which affect functions progressively, affect, first, the higher function, and then the others in order of rank, the rank being determined by the order of development in the individual; the intellectual being the last acquired are the first to be affected. Respiration and circulation being the first acquired by the organism are the last to be affected. This is well illustrated in the action of alcohol. This is called the *law of dissolution*. 2. Those drugs which in moderate dose excite; in large dose depress and paralyze. Great care should be exercised in the use of alcohol in sickness, as by a large dose we may defeat the very purpose we seek by paralyzing, when we desire to stimulate. *Large doses of alcohol do not stimulate the heart, but depress it.*

[2] The effect of a given quantity of alcohol will depend very much on the individual. What to one would act as a stimulant might in another act as a narcotic.



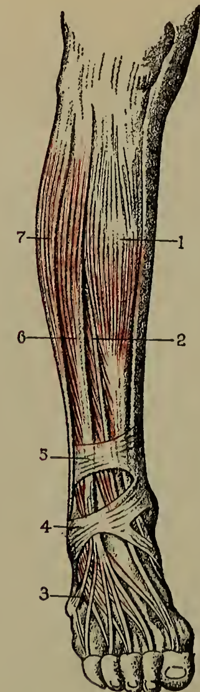


PLATE VI.

MUSCLES OF THE LOWER EXTREMITY.

FIG. 45.—Muscles of the thigh. 1. Iliopsoas. 2. Inguinal ligament. 3. Pectineus. 4. Adductor longus. 5. Gracilis. 6. Vastus internus. 7. Vastus externus. 8. Rectus femoris. 9. Sartorius. 10. Tensor vaginæ femoris. 11. Gluteus maximus.

FIG. 46.—Muscles of the leg. 1. Tibialis anticus; 2. Extensor proprius hallucis. 3. Peroneus tertius. 4. Annular ligament. 5. Transverse ligament. 6. Extensor longus digitorum. 7. Peroneus longus.

FIG. 47.—Muscles of the leg. 1. Plantar. 2. Gastrocnemius. 3. Soleus. 4. Tendo achillis.

tion of the nerve cells, (1) by the poor quality of the blood, and (2) by its narcotic effect on the metabolism of the cell, which may result in the injury of the tissue, producing what is called "softening of the brain."

Alcohol, when immoderately used, produces such a morbid craving for it that the person becomes, for the time being, entirely crazed in his craving for anything that will satisfy his consuming thirst,— a disease called *dipsomania*.

Persistent and inordinate use of alcohol may produce the dreadful and dangerous disease known as *delirium tremens*. Both of these diseases are acute forms of alcoholism, and are affections of the nervous system.

The effects do not stop here; these morbid conditions affect the health of the children of parents who are habitual users of alcohol, and even their children's children.

CHAPTER VI.

THE SKELETAL SYSTEM.

DEMONSTRATIONS AND EXPERIMENTS.

I. Make a careful study of the skeleton (Fig. 86), and notice: —

1. General arrangement of the bones.
2. How they are joined to the central column of bone (*vertebral column*).
3. The articulation of the arms at the shoulder, and the lower limbs at the hip bones.
4. What use do you see for the collar bones?
5. How are the ribs attached?
6. How many curves has the spinal column? What reason can you give for these curves?
7. How is the head attached to the spinal column?
8. How many separate bones (*vertebræ*) go to make up the spinal column?
9. What parts have vertebræ? (See Fig. 97.)
10. Is there any means of communication between the cavity of the skull and the canal of the spinal column (*spinal canal*)?
11. What organs are contained in the above-named cavities?
12. If nerves are given off by the spinal cord, how can they get out of the spinal canal? How could blood vessels enter the spinal canal?
13. Make a careful examination of the bones of the head.
14. How many of the bones have movable joints? Give reasons for the kinds of joints. What advantages are secured by the cranium being made of separate bones?
15. What use can you see for the numerous openings from the cranial cavity?
16. What provisions do you note in the form and structure of the orbit?
17. How does the size of the body of the vertebræ vary from above downward? What advantage is secured by this?
18. How do the form and size of the spinous processes differ? What advantage does this secure?

19. Notice the bones of the extremities. How are they adapted to their respective functions?

20. What provisions do you notice in the skeleton for the attachment of muscles?

21. Into how many classes can the bones be grouped as to their form?

22. From Fig. 86, also from Figs. 87 to 108, learn the names of the bones.

23. Read the description in the text, and see how it agrees with your own observations.

24. Notice the various joints of the body.

25. Taking the elbow, the humerus at the shoulder, the vertebræ, and the bones of the cranium as types, into how many groups can you class the joints of the skeleton?

26. Determine what joints belong to the types given.

27. Do you find joints which do not conform to the types given?

28. How does the knee joint differ from the elbow joint? Can you give a reason for the difference?

29. Compare the shoulder and hip joints. Give reasons for the difference.

30. Examine the humerus. Notice its expanded ends (*extremities*); the intervening portion (*the shaft*). What reasons can you give for the difference in the upper and lower extremities of the humerus?

31. Compare the humerus and the femur. Try to find reasons for the difference observed.

32. Are the bones which make movable articulation expanded at the portion articulating?

33. Make a longitudinal section of one of the long bones (Fig. 109) (a fresh bone).

a. Note structure of the extremities.

b. Note structure of the shaft.

c. Why are the extremities spongy and the shaft compact and hollow?

d. Notice the membrane (*periosteum*) surrounding the bone.

e. The lining (*endosteum*) of the cavity (*medullary canal*).

f. The nature of the substance (*marrow*) contained in the canal of the shaft. Take a small amount of marrow from the medullary canal, tease and examine with both high

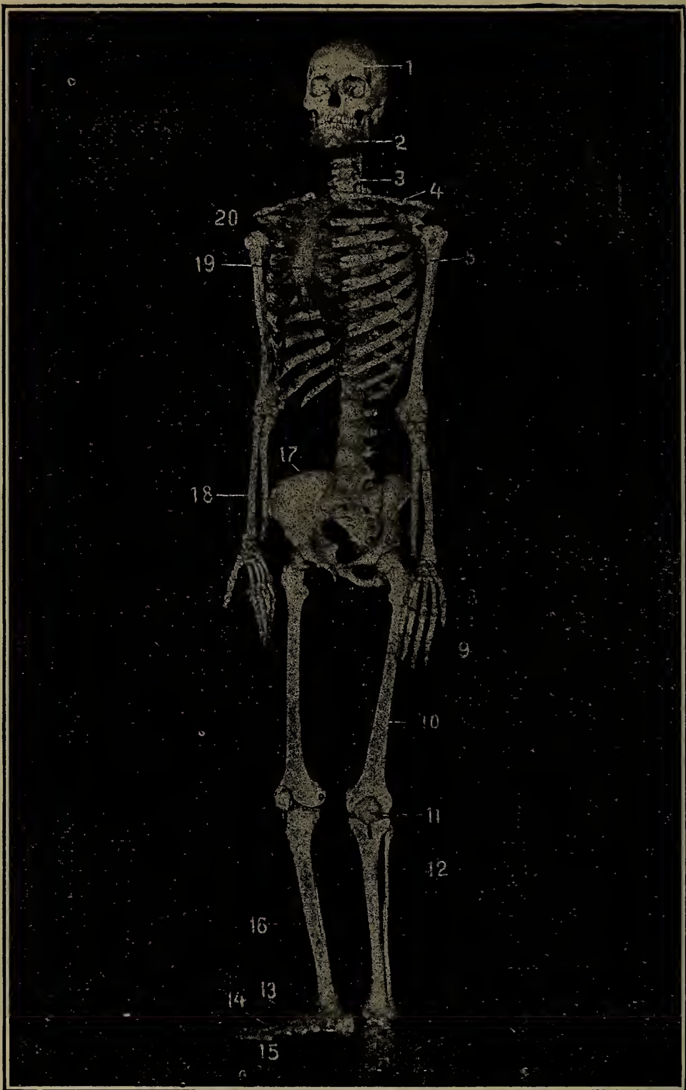


FIG. 86. — THE SKELETON.

1. Cranium. 2. Inferior Maxillary. 3. Spinal Column. 4. Clavicle. 5. Humerus. 6. Ulna. 7. Carpal bones. 8. Metacarpal bones. 9. Phalanges. 10. Femur. 11. Patella. 12. Fibula. 13. Tarsal bones. 14. Metatarsal. 15. Phalanges. 16. Tibia. 17. Pelvis. 18. Radius. 19. Sternum. 20. Scapula. (Brinckley.)

SKELETON					
Axial	Head	Skull		Frontal	1
				Parietal	2
				Occipital	1
				Temporal	2
				Sphenoid	1
				Ethmoid	1
		Ear		Malleus	2
				Incus	2
				Stapes	2
		Face		Malar	2
				Lachrymal	2
				Nasal	2
				Vomer	1
				Turbinated	2
				Superior Maxillary	2
				Palate	2
				Inferior Maxillary	1
	Chest			Ribs	24
				Sternum	1
				Hyoid	1
	Spine			Cervical	7
				Dorsal	12
				Lumbar	5
				Sacrum	1
				Coccyx	1
Appendicular	Upper Extremity	Shoulder		Scapula	2
				Clavicle	2
		Arm		Humerus	2
		Forearm		Radius	2
				Ulna	2
		Hand	Carpus: Upper Row	Scaphoid	2
				Semilunar	2
				Cuneiform	2
				Pisiform	2
			Carpus: Lower Row	Trapezium	2
				Trapezoid	2
				Os magnum	2
				Unciform	2
				Metacarpal	10
				Phalanges	28
	Lower Extremity	Hip		Os Innominatum	2
		Thigh		Femur	2
		Leg		Tibia	2
				Fibula	2
				Patella	2
		Foot		Os Calcis	2
				Astragalus	2
				Cuboid	2
				Navicular	2
				Internal Cuneiform	2
				Middle Cuneiform	2
				External Cuneiform	2
				Metatarsal	10
				Phalanges	28

and low power. Examine some of the marrow (red) from the spongy portion of the long bone. Compare structure with the marrow taken from the medullary canal. Determine whether the marrow contains any oil by soaking two grams or thirty grains of marrow in eight or ten times its volume of benzine for forty-eight hours. Pour off the benzine solution, and let it evaporate from a beaker or evaporating dish. Compare the weight of the oil obtained with the weight of the marrow taken. Express proportion in per cent. Burn twenty grams or three hundred grains of marrow in a porcelain crucible, and determine the amount of ash. Express in per cent. Make a solution of the ash, and test for sodium potassium, calcium, and phosphates. (See General Test in Appendix.) Does marrow contain proteids? Determine the amount of water in the yellow marrow by thoroughly drying twenty grams at 120° C. How much has it lost in weight by drying? What per cent of the marrow is water?

g. Do you find any place on the bones for the entrance of blood vessels?

34. Make a vertical section of a small piece of one of the flat bones, and note its structure, as before. Take care to have piece of uniform thickness, and as thin as possible. (See Appendix.) Mount dry, making ring of Brunswick Black to hold cover. Examine with three-fourths or two-thirds objective; compare with Figs. 22 and 23, and determine name of parts. Examine with one-sixth objective. Make a longitudinal section in the same way. What is the direction of most of the *Haversian canals* (see Fig. 23)?

35. Take a fresh bone (the femur of a cat, dog, rabbit, or chicken), and soak for several hours in dilute acid (muriatic, one part to ten parts of water). Remove the bone from the solution, and wash it to remove the acid. Set the solution away, as you will need it again. What changes do you notice in the bone? Dry, and weigh the bone. Boil the bone for several hours in several times its own volume of water, and then set away to cool. Test the gelatinous substance obtained for proteids. What does the test show in regard to the composition of the bone? Evaporate to dryness over a sand bath the liquid in which the bone soaked. After letting the powder cool, weigh it carefully. The powder you obtain is the mineral matter of the bone, that has dissolved in the

acid. How does its weight compare with the weight of the bone before it was treated with the acid? How does the weight of the bone after being treated with acid and drying compare with the first weight of the bone? What part of the bone is animal matter? What part mineral? Dissolve the powder from the evaporation of the liquid in which the bone was soaked, in distilled water, test (see Appendix) for magnesium, calcium, potassium, and phosphates.

Weigh a fresh bone, and then burn over a Bunsen flame on a piece of platinum foil, or in a porcelain crucible. If you do not have either of these, burn on a shovel over the coals in the stove. Weigh the ashes, and compare with the weight of the bone. How does this proportion compare with the proportion of mineral obtained in 35? Divide the ashes into three parts, and test (see Appendix) the first part for carbonates, the second for chlorides, and the third for phosphates. How does your analysis agree with that given in the text?

THE JOINTS.

1. Examine the kneejoint of the rabbit, dissect out the bands (*ligaments*) which bind the bones. In how many ways do they run? Are they all alike in form? Determine by means of the microscope their structure. How do you account for the moist surface where the parts come in contact? Make a section to show structure of the inner or smooth surface (*synovial membrane*). Make a longitudinal section of the head of the bones, and notice the cap of cartilage that tips the bones. Of what use is it to the joint? How many kinds of ligaments do you find? Examine in a similar manner the joint at the fore foot? Notice relation of the tendons and ligaments. How is the friction of the tendons prevented?

2. Dissect out one of the joints of the vertebral column. Notice the arrangement of the ligaments. How do you account for the cartilage (*interarticular*) between the vertebræ?

3. Examine some of the grooves over which tendons move, as the lower part of the forearm. Examine the membrane of the smooth surface over which the tendons move. Is it like the membrane you found in the joints?

4. Test the synovial fluid for proteids. Does it contain corpuscles? Does it coagulate on standing?

THE SKELETON. — TEXT.

Use of Bones.— As we have seen, motion is necessary to the welfare of the body. The muscles would be almost useless without firmer parts upon which to act. Again, many parts of the body are soft and delicate, and need support and protection. To serve these functions, we have the framework of the body, consisting of the firm, hard parts (*bones*), the softer and more elastic part (*cartilage*), found between the bones, and sometimes tipping the bones, and the band-like parts (*ligaments*) joining the bones together.

The tendons, which attach the muscles to the bones, and the connective tissue which enters as a supporting tissue into every organ of the body, also belong to the framework of the body.

In speaking of the skeleton, we generally have reference to the bones of the body, but the skeleton includes not only the bones, but the cartilage and ligaments which enter into the make-up of the joints, and when thus preserved, is known as a *natural skeleton.* But the skeleton is difficult to preserve in this condition, and the bones are generally put together by means of wire or bolts, or otherwise, and when thus put together, it is called an *artificial skeleton.*

Divisions of the Skeleton.— The skeleton is composed of (1) the central column of small bones (*vertebral column*) and the head, which make up the *axial skeleton,* and (2) the pectoral girdle, the upper extremities, the pelvic girdle, and the bones of the lower extremities, which make up the *appendicular skeleton.*

For convenience in study, the skeleton may be divided into the regions head, trunk, upper and lower extremities.

The head is made up of twenty-eight bones, consisting of those of the cranium, the face, and the ear.

Bones of the Cranium.— The bones of the cranium are eight in number. Each bone is composed of an external and an internal plate, with cellular bone (*diploe*) between them.

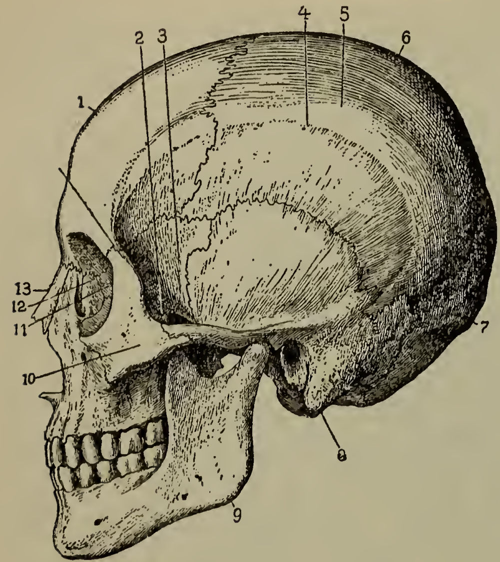


FIG. 87.—SIDE VIEW OF THE SKULL.

1. Frontal bone. 2. Zygoma of temporal bone. 3. Greater wing of the sphenoid. 4. Inferior temporal ridge. 5. Superior temporal ridge. 6. Parietal bone. 7. Occipital bone. 8. Mastoid process. 9. Inferior maxillary bone. 10. Malar bone. 11. Ethmoid bone. 12. Lachrymal bone. 13. Nasal bone.

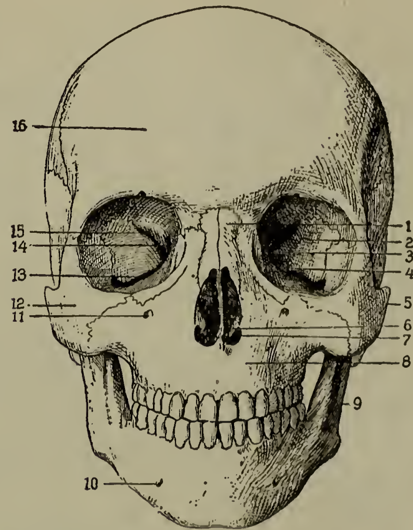


FIG. 88.—FRONT VIEW OF THE SKULL.

1. Nasal bone. 2. Sphenoid bone. 3. Ethmoid bone. 4. Lachrymal bone. 5. Zygoma. 6. Inferior turbinated. 7. Vomer bone. 8. Superior maxillary. 9. Inferior maxillary. 10. Mental foramen. 11. Infraorbital foramen. 12. Malar bone. 13. Inferior orbital fissure. 14. Optic foramen. 15. Superior orbital fissure. 16. Frontal bone.

The bone in the fore part of the cranium is the *frontal;* it is convex on the outside and concave on the inside, its inner surface being marked for the convolution of the brain. The prominent ridge on its lower portion is the orbital process, which roofs the orbit of the eyes. Above the orbital ridge (Fig. 88) are two cavities (*frontal sinus*), which are lined with mucous membrane, and communicate with cavities in the ethmoid bone. It articulates above with the two parietal bones (Fig. 87), below with the sphenoid (Fig. 89), ethmoid, superior maxillary (Fig. 87), lachrymal, and malar, and in front with the nasal (Fig. 87).

Parietal Bones.—The bones which form the side walls of the cranium are called the *parietal bones.* They are quadrilateral in form, smooth on their outer surface, but internally marked for the convolutions of the cerebrum. The lower portion on the outside is overlapped by the squamous portion (Fig. 87) of the temporal bone. In front it articulates with the sphenoid and the frontal, above with the opposite parietal, below and laterally with the temporal, and behind with the occipital (Fig. 87).

Occipital Bone.— The bone forming the back of the head is the *occipital bone* (Fig. 91). It also forms a part of the base of the cranium. It is round in form and the thickest of the cranial bones. The lower portion projects forward, forming what is called the *basilar process,* upon which rests the lower surface of the medulla oblongata. Just back of the basilar process is a large opening, called the *foramen magnum,* through which passes the spinal cord. On each side of this foramen is a projection of bone, forming the *occipital condyles,* which articulates with depressions in the atlas. It articulates in front with the parietal and the temporal, and below with the body of the sphenoid.

Temporal Bones.—At the side of and beneath the parietal bones, lie the *temporal bones* (Fig. 93). They are very irregular in form, and composed of three portions, an upper, scale-like part overlapping the parietal, and called the *squamous portion,* from the lower border of which there projects the *zygoma,* which forms, with a portion of the malar bone,

the *zygomatic* arch, to which are attached important muscles. At the base of this process is the cavity (*Glenoid*) with which the condyle of the inferior maxillary articulates. Back of this is the opening into the middle ear (*external meatus*).

Projecting forward and downward from this opening is a slender, rounded portion of bone, called the *styloid process* (Fig. 89), for the attachment of muscle going to the tongue and the hyoid bone. The rounded, conical-shaped projection back of this is called the *mastoid process,* for the attachment of the *sterno-cleido mastoid muscle.* It forms the greater part of the portion of the temporal bone, called the mastoid portion. It is very porous, and contains the mastoid cells, which are lined with mucous membrane, and have communication with the ear. The part of the temporal bone below the zygoma and in front of the mastoid process, is called the *petrous portion,* from its hardness; in it is hollowed out the cavities of the middle and internal ears. The temporal bone articulates with the parietal above, behind with the occipital, in front with the malar, the inferior maxillary, and sphenoid.

The Sphenoid Bone.—This bone is situated in the anterior part of the base of the cranium, and articulates with all the other bones of the cranium and five of the face, binding them firmly together, hence its name (the wedge bone). In form it resembles a bat with its wings spread. It articulates with the basilar process of the occipital, and forms a part of the floor on which the brain rests.

In the body of the sphenoid (Fig. 92) bone are two large, irregular cavities. These cavities are not found in children, but increase in size as age advances. Their thin walls aid much in the resonance of the voice. To the sphenoid are attached eleven muscles.

The Ethmoid Bone. — This bone is a very light and spongy bone, cubical in form, located at the anterior part of the base of the cranium between the two orbits, and at the root of the nose and entering in the formation of the orbits and the nasal fossa. It articulates with fifteen bones: the sphe-

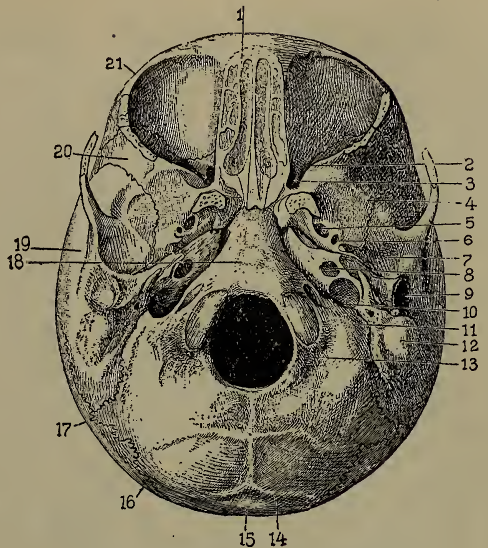


FIG. 89.—BASE OF SKULL, EXTERIOR.

1. Ethmoid bone. 2. Superior orbital fissure. 3. Optic foramen. 4. Greater wing of the sphenoid. 5. Foramen ovale. 6. Foramen spinosum. 7. Zygomatic fossa. 8. Carotid canal. 9. External meatus. 10. Jugular foramen. 11. Jugular process. 12. Mastoid process. 13. Occipital condyle. 14. Attachment of ligamentum nuchæ. 15. Ex-occipital protuberance. 16. Occipital bone. 17. Parietal bone. 18. Basilar process with pharyngeal spine. 19. Temporal bone. 20. Sphenoid bone. 21. Frontal bone.

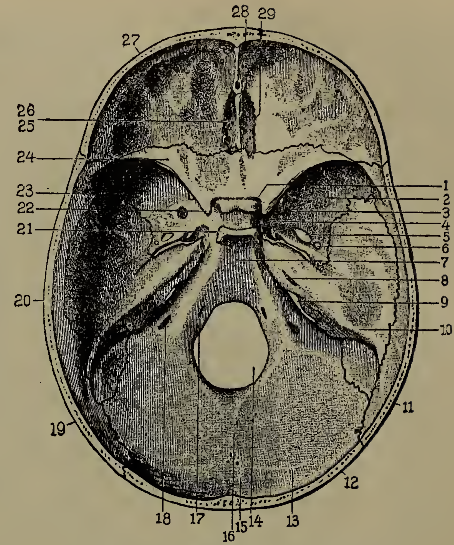


FIG. 90. — BASE OF SKULL, INTERIOR.

1. Optic foramen. 2. Superior orbital fissure. 3. Foramen rotundum. 4. Foramen lacerum. 5. Foramen ovale. 6. Foramen spinosum. 7. Basilar process. 8. Internal meatus. 9. Jugular foramen. 10. Ang. sup. pyram. 11. Parietal bone. 12. Occipital bone. 13. Lateral sinus. 14. Foramen magnum. 15. Sagittal sinus. 16. Occipital sinus. 17. Hypoglossal foramen. 18. Condyloid foramen. 19. Posterior fossa. 20. Median fossa. 21. Posterior clinoid process. 22. Anterior clinoid process. 23. Sphenoid bone. 24. Wing of the sphenoid. 25. Ethmoid bone. 26. Anterior fossa. 27. Frontal bone. 28. Crista galli. 29. Cribiform plate of ethmoid.

noid, the frontal, the nasal, the superior maxillary, larchrymal, palate, interior turbinated, and the vomer. There are no muscles attached to the ethmoid.

Bones of the Face.— There are fourteen bones in the face; viz., the two nasal, two superior maxillary, two lachrymal, two malar, two palate, two inferior turbinated, one vomer, and one inferior maxillary.

The upper and lower jaws are the fundamental bones of mastication, the other bones of the face being accessory; the chief function of the bones of the face being to provide an apparatus for mastication, and having a secondary function of providing for the sense organs (eye, nose, tongue), and a cavity for the respiratory and vocal organs. "Hence the variation in the shape of the face in man and the lower animals depends chiefly on the question of the character of the food and their mode of obtaining it."

The Nasal Bones.— These two bones are placed side by side, forming the bridge of the nose. They are small, oblong, and varying in size in different individuals. They articulate with four bones, the frontal and ethmoid, the opposite nasal, and the superior maxillary. They receive a few fibers of the *occipito-frontalis* muscle.

The Superior Maxillary Bones.—They (Fig. 94) are situated beneath the nose and between the cheek bones. The superior maxilla presents for study a body somewhat cuboid in form, hollowed out in its interior to form a large cavity called the *antrum of Highmore,* and four processes: the malar, the portion articulating with the cheek bones; the nasal, forming part of the cavity of the nose; the palatal, the thin portion of bone forming the greater part of the roof of the mouth; and the alveolar, the portion of the bone in which the teeth are set. Excepting the lower jaw, it is the largest bone of the face, forming by its union with its fellow of the opposite, the whole of the upper jaw. It articulates with nine bones, the frontal, ethmoid, the nasal, vomer, malar, lachrymal, inferior turbinated, palate, and the opposite maxillary.

To it are attached twelve muscles, the more important of which are the orbicularis palpebrarum, masseter, buccinator, internal pterygoid, and orbicularis oris (Fig. 36).

Not only is it of interest from the part it plays in mastication, but as well from a surgical point of view, from the various diseases to which its parts are liable. The antrum is lined with mucous membrane, and communicates with the nasal fossæ; the thin walls of this cavity add much to the resonance of the air passages.

The Lachrymal Bones.— They (Fig. 88) are located in the fore part of the orbit, resembling in form, thickness, and size a finger nail. These two bones are the smallest and most fragile bones of the face. Each bone has one muscle attached to it, and has articulation with the frontal, ethmoid, superior maxillary, and inferior turbinated.

The Malar Bones.— These two small bones (Fig. 88), situated at the upper and outer part of the face, form the prominence of the cheek and part of the outer wall and floor of the orbit. They are quadrangular in form, and articulate with the frontal, sphenoid, temporal, and the superior maxillary. Each malar bone forms attachment for five muscles, the more important of which are fibers from the temporal and masseter muscles.

The Palate Bones. — They are (Fig. 94) situated at the back part of the nasal fossæ, being wedged in between the superior maxillary and one of the processes (*pterygoid*) of the sphenoid. They are somewhat L-shaped, and so placed that the short part of the L forms a part of the hard palate, and the longer portion forms a part of the nasal fossæ. Each bone has six articulations, the sphenoid, ethmoid, superior maxillary, inferior turbinated, vomer, and the opposite palate. Each forms attachment for four muscles.

The Inferior Turbinated.— These scroll-shaped bones are situated one on each side of the outer wall of the nasal fossæ. Each articulates with four bones, the ethmoid, superior maxillary, lachrymal, and palate. They have no muscles attached to them.

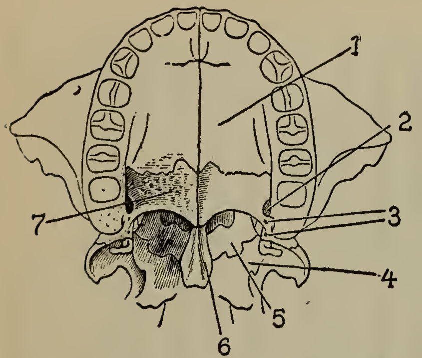


FIG. 94.—SUPERIOR MAXILLARY BONE SEEN FROM BELOW.

1. Palatal process. 2. Greater palatal foramen. 3. Accessory palatal foramen. 4. Pterygoid process. 5. Sphenoid process. 6. Vomer. 7. Palate bone.

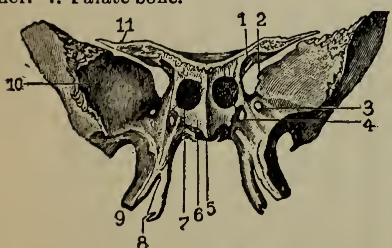


FIG. 92.—SPHENOID BONE, ANTERIOR.

1. Optic foramen. 2. Superior orbital fissure. 3. Foramen rotundum. 4. Vidian foramen. 5. Rostrum of sphenoid. 6. Concha of sphenoid. 7. Sphenoid sinus. 8. Hamular process. 9. Pterygoid process. 10. Orbital surface. 11. Wing of orbit.

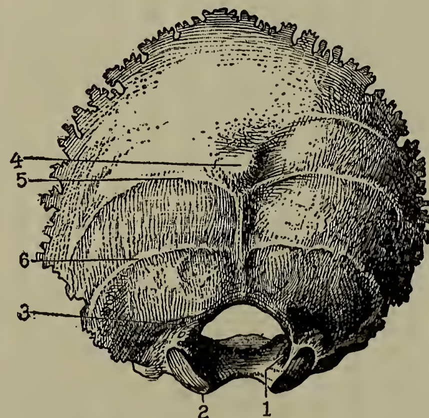


FIG. 91.—OCCIPITAL BONE, EXTERIOR.

1. Anterior condyloid foramen. 2. Condyle. 3. Posterior condyloid foramen. 4. Occipital protuberance. 5. Superior curved line. 6. Inferior curved line.

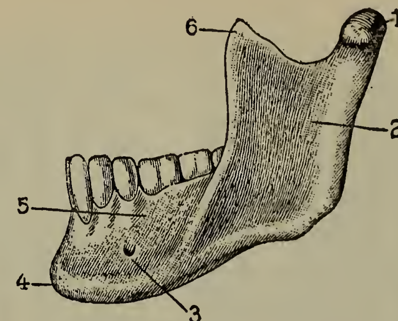


FIG. 95.—INFERIOR MAXILLARY.

1. Condyle. 2. Ramus. 3. Mental foramen. 4. Mental process. 5. Alveolar process. 6. Coronoid process.

FIG. 93.—TEMPORAL BONE. (Lateral.)

1. Mastoid process. 2. Petrous portion. 3. Meatus auditorius externus. 4. Glenoid fossa. 5. Zygoma.

The Vomer.—This is a single bone, and resembles a plowshare, varying very much in size and form in different individuals. It articulates with six bones: the ethmoid and sphenoid of the cranium, and with the two superior maxillary, the two palate bones of the face, and with the cartilage of the septum of the bone. There are no muscles attached to the vomer.

The Inferior Maxillary Bone.—It (Fig. 95) is situated beneath the superior maxillary, the upper portion by the posterior process (*condyloid process*), articulating with the glenoid fossæ of the temporal bones. It is the largest and strongest bone of the face. It is made up of a curved horizontal portion which has the form of a horseshoe, *the body* and two perpendicular portions, the *rami*, which join with the body at nearly a right angle. The form varies very much with the age.

On the horizontal portion is the *alveolar process*, in which are set the lower teeth. The inferior maxillary serves for the attachment of fifteen pairs of muscles, the more important of which are the buccinnator, masseter, orbicularis, digastric, temporal, and pterygoid.

Hyoid Bone.—It is situated at the base of the tongue, to which it gives support and attachment. In general outline it is U-shaped, and consists of a body and four processes called cornua, two of which are large and two small. It articulates with no bones.

It serves for the attachment of numerous muscles, especially of the tongue, larynx, and pharynx.

THE THORAX.

This forms the protecting cage which contains the principal organs of respiration and circulation. It is conical in form, being narrow above and broad below, flattened from before backward, and longer behind than in front. On transverse section it is somewhat heart-shaped. Its posterior support is the dorsal vertebræ. Its bony walls consist of the ribs, costal cartilage, and the sternum.

The Sternum.— This bone forms the line of support in front. It (Fig. 100) is a flat, narrow bone, made up in the adult of three pieces; and from its fancied resemblance to an ancient sword, these have been called, (1) the *manubrium* — the upper piece, or handle; (2) the *gladiolus* — the middle piece, or blade; (3) the *ensiform,* or *xiphoid appendix* — the lower piece, or tip of the sword.

It has numerous indentations for the reception of the costal cartilage. The upper part of the manubrium is curved to receive the clavicle. It articulates with the clavicles and seven pairs of costal cartilage. It serves for the attachment of nine pairs and one single muscle, the diaphragm.

The Ribs.— These (Fig. 100) form the side bars of the thorax, and extend, with the exception of two pairs, from the costal cartilage in front of the vertebræ behind, with which they have articulation at two points: the facets of the body of the vertebræ and the transverse process.

They are so placed, one below the other, that spaces are left between them, called intercostal spaces. The ribs consist of twelve pairs, seven of which are attached to the sternum by the costal cartilages, and are called true ribs. The remaining five are called false ribs; the first three pairs are attached by cartilage to the rib above; of these the last two are free at their anterior extremity, and are called floating ribs.

Typically, a rib consists of two extremities, a posterior or vertebral and an anterior or sternal, with an intervening portion, the body, or shaft. This is best seen in the ribs from the middle of the series. The posterior extremity consists of a head having a kidney-shaped articulating surface, and the neck, which is the flattened portion, and which extends outward from the head. On the neck there is an eminence, *tubercle,* where the rib articulates with the transverse process of the vertebræ.

The shaft is thin and flat, and differently curved in the different ribs (see Fig. 100). While the ribs have the features mentioned in common, they differ very much in themselves to adapt them to their special uses.

The ribs have twenty pairs of muscles attached to them; among the more important of these may be mentioned the internal and external intercostals, scaleni, and diaphragm, which are concerned in respiration.

Fig. 96.—Side View of Spinal Column.
1. Atlas. 2. Axis. 3. The seventh cervical vertebra. 4. First dorsal vertebra. 6. Twelfth dorsal vertebra. 5. First lumbar. 7. Fifth lumbar. 8. Sacrum. 9. Coccyx.

THE VERTEBRAL COLUMN.

The spine, or vertebral column, forms the posterior and axial part of the skeleton. It is divided into three regions, the cervical, the dorsal, and the lumbar (Fig. 96). In man the spinal column has four curves: convex anteriorly in the cervical region, concave in the dorsal, convex in the lumbar, and concave in the pelvis. It is smaller above, and increases quite gradually to the sacrum.

The separate bones are called *vertebra;* twenty-four of these are called true vertebra, and nine are called false (the sacrum five, and the coccyx three or four), as they are scarcely movable.

Most of the vertebræ (Fig. 96) consist of a *body,* the anterior portion, from which there projects two thin layers which meet posteriorly, and from the neural arch, from which project seven *processes* — two pointing upward and two pointing downward, the *articular processes;* two pointing laterally, the *transverse processes;* and one backward, the *spinous process.* In the lower portion of the pedicel is a groove over which the spinal nerves and the blood vessels pass.

The pedicels with the *laminæ* form a ring, the neural arch, and these placed one upon the other form the neural canal, in which is contained the spinal cord. Between each of the bodies of the vertebræ are pads of cartilage; the bodies are also rimmed with car-

tilage, thus adding much to the flexibility and elasticity of the vertebral column, and increasing the power of movement of the trunk of the body. The vertebræ are firmly bound together by ligaments, giving not only freedom of movement in bending, but great strength also. The separate vertebræ with the interarticular cartilages lessen very much the shocks on the brain which it would receive were it not for this protection.

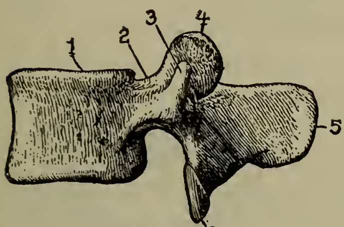


FIG. 97. A.—A VERTEBRA, SIDE VIEW.

1. Body. 2. Pedicel. 3. Transverse process. 4. Superior articular process. 5. Spinous process. 6. Inferior articular process.

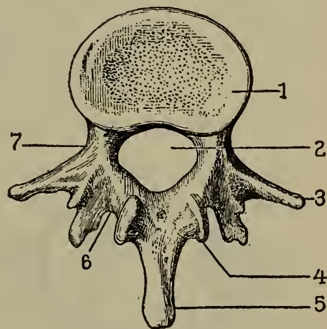


FIG. 97. B.—A VERTEBRA, SEEN FROM BELOW.

1. Body. 2. Vertebral foramen. 3. Transverse process. 4. Inferior articular process. 5. Spinous process. 6. Pedicel. 7. Lamina.

The curves in the spinal column serve not only to give beauty to the outline of the body, but are so arranged that the direction of the line of shock falls outside of the brain, giving it security from injury from this source.

The first two of the cervical vertebræ are very much modified to adapt them to their special function. The first of the cervical vertebræ is called the *atlas*. It surmounts the vertebral column, and articulates with the cranium. It is without spinous process and body.

On its upper surface are two depressions for the reception of the occipital condyles of the cranium. The *neural arch* is large, and receives in its anterior portion the *odontoid process,* which is held in place by the check ligament (Fig. 98). The second cervical is called the *axis*. From its body arises the odontoid process (Fig. 99), which forms the axis of rota-

tion of the head. The foramen in the transverse process are for the passage of the vertebral artery.

Pectoral Girdle.— To the vertebral column are attached two girdles to the first dorsal; the *pectoral girdle* (Fig. 100), consisting of two *f*-shaped bones, the *clavicles,* and two flat, irregular bones, the *scapulas.* The clavicles (Fig. 100) articulate in front with the sternum, and posteriorly with the scapula. The scapula (Fig. 101) is very irregular and marked by ridges, the more prominent being called the *spine.* The ridges give attachment to muscles. The round cavity (*glenoid cavity*) in the scapula is made deeper by a rim of cartilage, and receives the head of the humerus. The

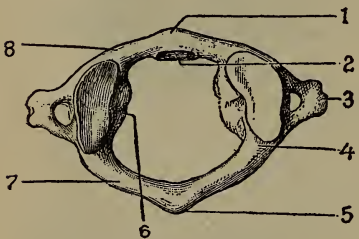


FIG. 98.—THE ATLAS.
1. Anterior tubercle. 2. Depression to receive the odontoid process. 3. Transverse process. 4. Sinus for vertebral artery. 5. Posterior tubercle. 6. Lateral mass. 7. Posterior arch. 8. Anterior arch.

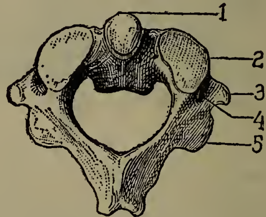


FIG. 99.—THE AXIS.
1. Odontoid process. 2. Superior articulating surface. 3. Transverse articular process. 4. Foramen for vertebral artery. 5. Inferior articular process.

large process projecting forward and articulating with the clavicle is the *acromion process.* The hook-shaped process is called the *coracoid process.* The scapula has no articulation posteriorly, but rests in the flesh, supported by muscles and ligaments, hence the ease of its dislocation.

Pelvic Girdle. — The pelvic girdle (Figs. 100 and 105) consists of the *ossa innominata,* which articulate with the sacrum posteriorly. This forms a bony basin, the *pelvis,* which gives attachment to strong muscles, and also support to the abdominal viscera. The large foramen in the innominata is called the *obturator foramen,* and through it passes the obturator nerves and vessels; the greater part of the opening is filled by a membrane.

The hemisphere-shaped cavity, called the *acetabulum,* is for the reception of the head of the femur. Like the glenoid cavity, it is deepened by a rim of cartilage.

The sacrum and coccyx are really modified vertebræ.

The *sacrum* (Fig. 105) is wedge shaped, articulating above with the last lumbar, below with the coccyx, and laterally with the innominata. It has prominent intervertebral foramina. The *coccyx* is small, consisting of four or six bones which diminish in size from the sacrum. In the adult they usually become united into one bone.

THE UPPER EXTREMITIES.

The bones of the upper extremities are the scapula, clavicle (forming the *pectoral girdle*), humerus, radius and ulna, carpal bones, metacarpal bones, and phalanges.

The Arm. — This consists of one bone, the *humerus* (Fig. 102), a long cylindrical bone consisting of a head, a slightly defined neck, a shaft, and its lower portion, two condyles.

The head is hemispherical, and fits into the glenoid cavity. On the anterior surface of the lower extremity is the cavity (*lesser sigmoid*) for the reception of the *coronoid process* of the ulna, on the posterior is a large cavity (*greater sigmoid*) for the reception of the *olecranon process* of the ulna (Fig. 103).

Forearm.— The forearm (Fig. 103) consists of two bones, the *radius* on the thumb side and the *ulna* on the little finger side. The radius has at its upper portion a rounded head having a shallow depression which meets a slight projection in the lower end of the humerus. Just below the head (the neck) there is attached a ligament in which the radius turns. The tubercle below the neck is for the attachment of the tendon of the biceps muscle. The lower end is broadened to make articulation with the bones of the wrist (*carpal bones*). The sharp projection (*styloid process*) is for the attachment of a ligament. The grooves on the posterior of the lower portion are for the passage of the tendons of the extensor muscles of the hand.

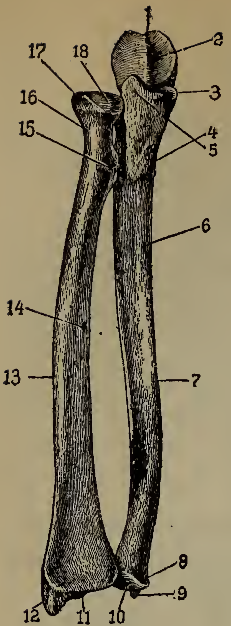


FIG. 103.—RIGHT RADIUS AND ULNA, ANTERIOR VIEW.

1. Olecranon. 2. Greater sigmoid cavity. 3. Lesser sigmoid cavity. 4. Tubercle of the ulna. 5. Coronoid process. 6. Nutrient foramen. 7. Ulna. 8. Head. 9. Styloid process. 10. Articular surface. 11. Head of radius. 12. Styloid process. 13. Radius. 14. Nutrient foramen. 15. Bicipital tuberosity. 16. Neck. 17. Head. 18. Articulating surface.

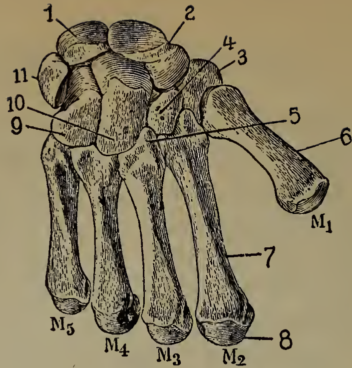


FIG. 104.—CARPAL AND METACARPAL BONES.

1. Semilunar. 2. Scaphoid. 3. Trapezium. 4. Trapezoid. 5. Head of metacarpal bone (proximal). 6. First metacarpal bone. 7. Shaft. 8. Head (distal). 9. Unciform. 10. Os magnum. 11. Cuneiform. 12. The pisiform bone (not shown in cut). M_1, M_2, M_3, M^4, and M_5, metacarpal bones.

FIG. 102.—RIGHT HUMERUS, ANTERIOR VIEW.

1. Head. 2. Posterior bicipital ridge. 3. Attachment for teres major muscle. 4. Coraco-Brachiales (attachment). 5. Anterior border. 6. Median border. 7. Coronoid fossa. 8. Internal condyle. 9. Trochlear head. 10. Radial head. 11. External condyle. 12. Radial fossa. 13. Lateral border. 14. Deltoid tuberosity. 15. Pectoralis major (attach.). 16. Anterior bicipital ridge. 17. Lesser tuberosity. 18. Bicipital groove. 19. Greater tuberosity. 20. Surgical neck.

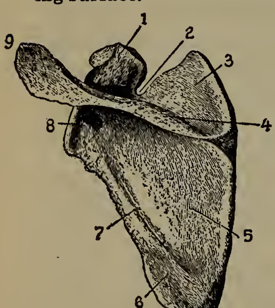


FIG. 101.—THE SCAPULA.

1. Coracoid process. 2. Suprascapular notch. 3. Supraspinous fossa. 4. Spine. 5. Infraspinous fossa. 6. Attachment for teres major muscle. 7. Attachment for the teres minor. 8. Rim of the glenoid cavity. 9. Acromium process.

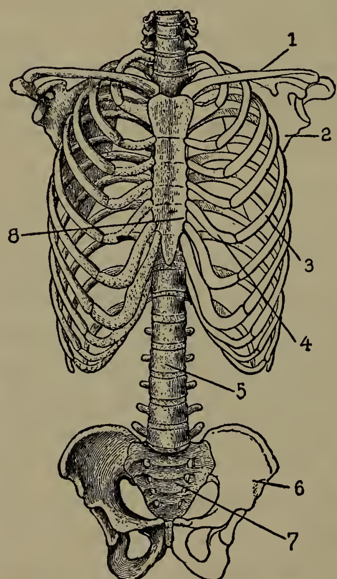


FIG. 100.—CHEST, PECTORAL GIRDLE, AND PELVIC GIRDLE.

1. Clavicle. 2. Scapula. 3. Ribs. 4. Costal cartilage. 5. Vertebral column. 6. Os innominatum. 7. Sacrum. 8. Sternum.

The ulna is longer than the radius. It is largest at its upper end to form the articulation with the humerus. The portion projecting backward is called the *olecranon process.* In the upper portion are two curved depressions (*greater and lesser sigmoid cavity*), the greater, for the reception of the humerus, and the smaller for the head of the radius. The hook-like process is called the *coronoid process,* which fits over the lower head of the humerus (Fig. 102). The lower end is flattened, and articulates with the radius. The long projection from the inner side (the *styloid process*) is for the attachment of a ligament.

Carpus.— The carpus (Fig. 104), or wrist bones, are eight in number; in general form, cuboidal. Their names and position may be learned from Fig. 104.

Metacarpal Bones.— These are situated beyond the carpal bones, being five in number, and form the palm of the hand. They are the long bones in form, being made up of two extremities and a shaft. The extremities articulate with the wrist bones, have facets for the reception of last row of carpal bones; the portion articulating with the first phalanges has a rounded head, giving more surface for articulation and greater freedom of motion.

Fingers.— The finger and thumb bones are known as *phalanges.* In the fingers there are three rows; in the thumb, two. The first and second rows of bone resemble the metacarpal bones in their form and structure, but they are shorter. The last row is flattened to adapt them to support the nails.

THE LOWER EXTREMITIES.

Femur.—The femur (Fig. 106), or thigh bone, is the longest bone of the body. At its upper end is a hemispherical head supported by a well-defined neck, which joins the shaft at an obtuse angle. The projection from the upper part of the shaft is the *greater trochanter;* beneath it on the opposite side is the *lesser trochanter.* These projections serve for the attachment of muscles. The shaft is round, strong, and marked by a prominent ridge (*linea aspera*).

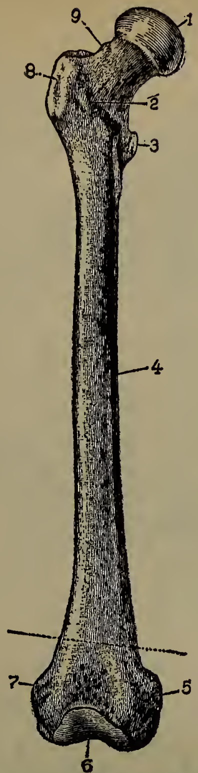


Fig. 106.—Right Femur, Anterior View.

1. Head. 2. Oblique line. 3. Lesser trochanter. 4. Median border. 5. Inner tuberosity. 6. Facet for patella. 7. Outer tuberosity. 8. Greater trochanter. 9. Neck.

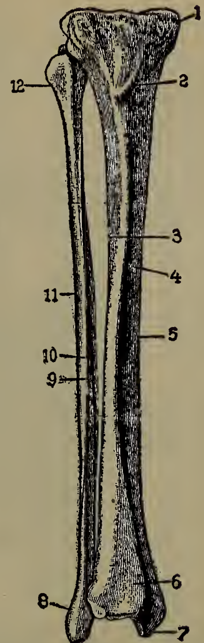


Fig. 107.—Tibia and Fibula, Anterior View.

1. Head of tibia. 2. Tubercle of the tibia. 3. Interosseous crest. 4. Anterior crest. 5. Tibia. 6. Head. 7. Internal malleolus. 8. External malleolus of the fibula. 9. Anterior crest of the fibula. 10. Interosseous crest. 11. Fibula. 12. Head.

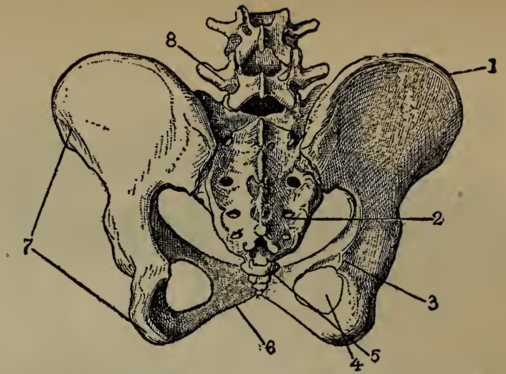


Fig. 105.—Posterior View of Pelvic Girdle.

1. Ilium. 2. Sacrum. 3. Spine of the ischium. 4. Obturator foramen. 5. Coccyx. 6. Arch of pubis. 7 Innominate. 8. Lumbar vertebra.

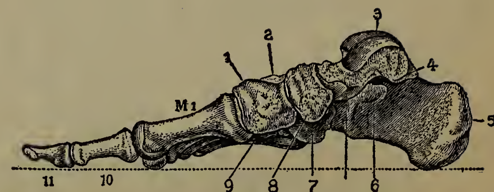


Fig. 108.—The Foot.

1. Internal cuneiform. 2. Middle cuneiform. 3. Astragalus. 4. Facet for flexor longus hallucis. 5. Os calcis. 6. Facet for flex. long. hallucis. 7. Internal cuneiform. 8. Navicular (scaphoid). 9. Fifth metatarsal bone. 10. First phalange of great toe. 11. Second phalange of great toe. M_1. First Metatarsal.

The lower end is expanded, and has two large condyles with rounded, smooth, articulating surfaces. Between the condyles is a depression for the *patella.*

Patella.— This (Fig. 86) is a flat bone of a roundish triangular shape. It rests in the tendon which passes beneath it to join with the tibia. Anteriorly it is covered by the skin. In its nature and origin it is a sesamoid bone.

Tibia.— This (Fig. 107) is the inner and the larger of the bones of the leg. Its upper surface is large, presenting two oval surfaces for articulation with the condyles of the femur. The lower extremity of the tibia is smaller than the upper, and it supports a large process (*internal malleolus*). The depression (*fossa*) on the outside is for the articulation with the fibula.

Fibula.— The *fibula* (Fig. 107) is placed external to the tibia. It articulates with the head of the tibia. It is slender and weak, the extremities being relatively small. The lower extremity has a process (*external malleolus*).

Tarsus.— The *tarsus* (Fig. 108) consists of seven bones, whose names may be learned from Fig. 108. Like those of the carpus, their general form is cuboidal. The tibia articulates with the *astragalus;* the heel is formed by the *os calcis,* to the posterior surface of which is attached the tendon of Achilles.

Metatarsal Bones.— They are five in number. They resemble the metacarpal bones in their structure, but are larger.

Phalanges.— These consist of the same number of bones, have the same arrangement and similar structure, as the phalanges of the hand.

Chemical Composition.— Bone is composed of earthy matter about sixty-seven per cent, and of animal matter thirty-three per cent. These are so intimately blended and incorporated that they can only be distinguished by chemical means, as burning or removal by acid. In case of removal of the earthy matter by acid, or the animal matter by burning, the form of the bone is preserved. The proportion of

these two ingredients of the bone varies in different bones and in the same individual, and in the same bone at different ages. The earthy material consists chiefly of calcium phosphate, with a small quantity of calcium carbonate, calcium fluoride, and magnesium phosphate, which make up about eleven of the sixty-seven per cent.

Structure.—When examined without the aid of the microscope, we notice two kinds of bone tissue, often in the different parts of the same bone; the dense or compact, and the spongy, or *cancellous bone.* The compact is represented in the outer and inner surfaces of the cranial bones; the spongy in the intervening bone. In the shaft of the long bones we notice the compact bone on the exterior and interior, and the spongy bone between. The extremities of the long bones are principally spongy bone. The cavity (Fig. 109) (*medullary canal*) in the shaft is filled with a fatty substance called *marrow,* which in the medullary cavity is called yellow marrow, and consists chiefly of fat cells with numerous blood vessels; there are also cells resembling the lymphoid corpuscles. In the spaces of the cancellous tissue is found a marrow called the red marrow. It is highly vascular, and maintains the nutrition of the spongy portion of the bones.

The red marrow contains some fat cells, a large number of marrow cells, many of which resemble lymphoid corpuscles, and have for their basis a small amount of fibrous tissue. There are also some nucleated cells of very much the same tint as the red corpuscles of the blood.

There are a few large cells called giant cells (*myeloplaxes*), probably derived from the overgrowth of the ordinary marrow cells. From the resemblance of the red cells to those of the red corpuscles it is thought that the marrow is a source of red corpuscles.

Periosteum and Nutrient Blood Vessels.— The surface of the bone, except the part covered by the articular cartilage, is covered by a tough, fibrous membrane, the *periosteum,* and from its blood vessels the bone receives some of its blood supply, especially the compact portion. These go into the

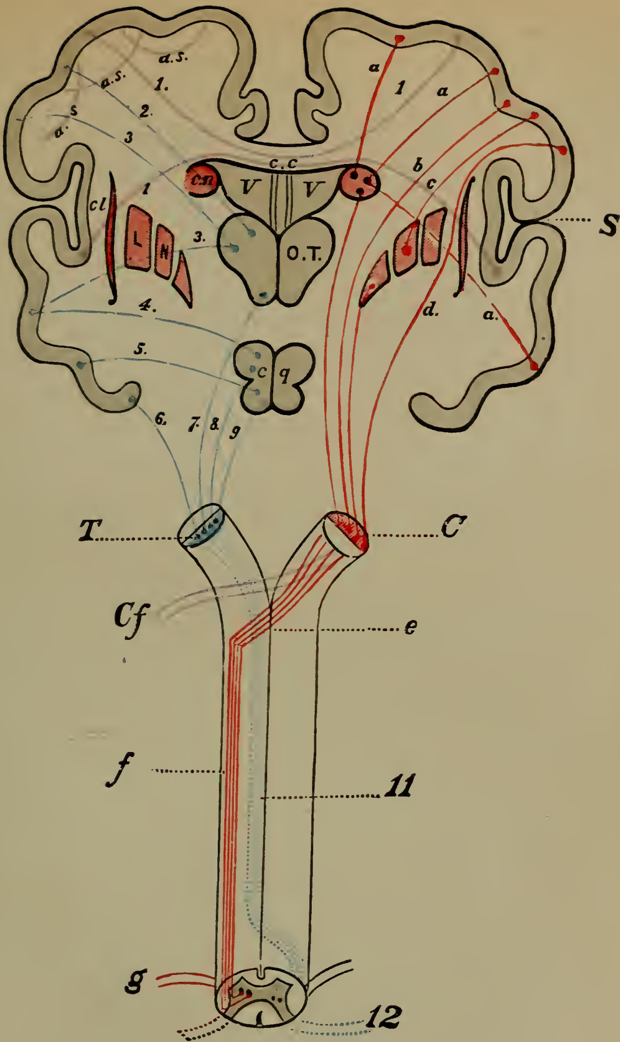


PLATE VII.

FIG. 70.—A DIAGRAM TO SHOW THE GENERAL ARRANGEMENT OF THE FIBERS OF THE CEREBROSPINAL SYSTEM.

(Modified from Landois.) (From Ranney.)

The shaded portions represent the collections of gray matter. On the left side of the diagram, the sensory fibers of the crus are traced upward from the spinal cord to various portions of the cerebrum; on the right side, the motor fibers are similarly represented. Numerals are used in designating the sensory and commissural fibers; the motor fibers are lettered in small type. The cortical layer is shown at the periphery of the cerebral section, with commissural fibers (1) connecting homologous regions of the hemispheres, and associating fibers (*a. s.*) connecting different convolutions of each hemisphere. *c. n.* Caudate nucleus of the corpus striatum. L. N. Lenticular nucleus of the same. O. T. Optic thalamus of each hemisphere united to each fellow in the median line. *c. q.* corpora quadrigemia. *c. l.* Claustrum, lying to the right of the letters. *c. c.* Corpus callosum, with its commissural fibers. *S.* Fissure of sylvius. *V.* Lateral ventricle, the fifth ventricle being shown between the two layers of the septum lucidum. *C.* the motor tract of the crus cerebri (basis cruris—crusta). *T.* The sensory tract of the crus cerebri (tegmentum cruris). *Cf.* The cerebellar fasciculus. *e.* The point of the decussation of the motor fibers of the spinal cord. *f.* The course of the decussating motor fibers of the spinal cord below the medulla, showing their connection with the cells of the anterior horns of the gray matter, and their continuation into the anterior roots of the spinal nerves (*g*). *a.* Fibers which radiate through the caudate nucleus. *b.* Fibers of the "internal capsule." *c.* Fibers which radiate through the lenticular nucleus. *d.* Fibers of the "external capsule." 2, 3, 4, 5, 6, 7, 8, 9, sensory fibers radiating from the tegmentum cruris to the cortex by means of various nodal masses of gray matter. 11. Course of the sensory fibers of the spinal cord (shown by dotted lines), intimately connected with the posterior root of the spinal nerve (12), and decussating at or near to the point of entrance into the spinal cord. In this diagram, the direct pyramidal fibers are not shown, nor the gray matter of the pons.

surface of the bone by numerous small openings; from these openings the small blood vessels find their way to the *Haversian canals.* The periosteum not only serves as a means of nourishment to the bone, but also as a means for the attachment of tendons and ligaments. The long bones have, in addition, special nutrient vessels which enter the shaft of the bone, and find their way to the medullary canal, and, breaking up into numerous branches, supply the marrow. Other small vessels pierce the articular extremities for the supply of the cancellous tissue.

Microscopic Structure.— While the cancellous and compact bone tissues differ in their coarse structure, they are essentially alike in their microscopic (Figs. 22 and 23) structure.

When examined with a high power, the substance of the bone is found to contain many small, irregular spaces approximately fusiform in shape, known as *lacunæ,* and containing the bone corpuscles or bone cells, and leading from these lacunæ are very minute canals (*canaliculi*) which anastomose with similar branches from other lacunæ. In longitudinal sections are seen round holes, which are sections of tubes which run for the most part longitudinally, but occasionally they give off cross branches. The average diameter of these tubes (*Haversian canals*) is one five hundredth of an inch. They are for the passage of blood vessels which enter the bone by the nutrient foramen. From the blood vessels of the Haversian canal, the lacunæ and canaliculi absorb nutrient matter, and convey it more intimately to the very substance of the bone which they traverse.

Development of Bone.— As to their mode of development bones may be divided into two classes: —

1. Those which are formed (*ossified*) direct, from the first, in membrane or fibrous tissue; e. g., parietal and occipital bones.

2. Those which, previous to ossification, were hyaline cartilage; e. g., humerus and femur.

The ossification of bone is too complex to be described

here. Those desiring to know more about it may read the footnote.[1]

From the study of the note just given it will be seen that the terms "ossification in cartilage," and "ossification in membrane" are apt to be misleading, since they seem to imply two processes radically distinct. The process of ossification is the same, however, be it cartilage or membrane, being from membrane, in each case from the perichondrium, or periosteum. In the development of a bone like that of the femur, which may be taken as the type of cartilage ossification, the lime salts are first deposited in the cartilage; this calcified cartilage, however, is gradually and entirely reabsorbed, being ultimately replaced by bone from the periosteum, till in the adult structure nothing but bone is left. In the ossification of cartilage, calcification of the cartilaginous matrix precedes the real formation of bone. We should therefore make a distinction between ossification and calci-

---

[1] The ossification of bone may be divided into the following six stages:—

1. The enlargement and proliferation of the cartilage cells and the formation of trabiculæ by the deposit of lime salts in the matrix of the cartilage and the change of the perichondrium to the periosteum (stage of *Proliferation and Calcification*).

2. Processes are given off from the cellular (*osteogenetic*) layer of the periosteum containing blood vessels which grow out into the substance of the cartilage, the process beginning at the centers of ossification and spreading up and down the shaft, etc., so that the cartilage which contains no blood vessels becomes grooved by a network of blood vessels (stage of *Vascularization*).

3. The arrangement of the cells of the primary marrow in contiguous layers like epithelium on the trabeculæ (calcified), depositing a layer of bone and ensheathing them. This is followed by the absorption of the trabeculæ by means of cells called *osteoclasts*, leaving the bone spongy and composed of young bone, the calcified cartilage being completely absorbed (stage of *Substitution of Embryonic Spongy Bone for Calcified Cartilage*).

4. The embryonic spongy bone is only a temporary tissue, the periosteum form around the embryonic bone, true bone, by the deposit at the circumference of the shaft. The embryonic spongy bone is absorbed through the agency of the osteoclasts; the trabeculæ absorbed, the cavity thus formed is called the "medullary canal of the shaft (stage of *Substitution of Periosteal Bone for the Primary Embryonic Bone*).

5. The work of absorption continues until all the bone — spongy bone — is absorbed. At the same time the periosteum is depositing new layers to those already deposited. The medullary canal is enlarged, and its boundary wall of periosteal bone thickened (stage of *Absorption of the Inner Layers of Periosteal Bone*).

6. The formation of compact bone now takes place, the irregular walls of the areolæ being absorbed; the osteoblast which line them forming themselves into concentric layers, each in its turn becoming ossified, forming a Haversian canal (stage of *Formation of Compact Bone*).

fication. Calcification is simply the infiltration of an animal tissue with lime salts, being a change of chemical composition rather than structure, while ossification is the formation of true bone, a tissue more complex and more highly organized than that from which it is derived. Compare the structure of hyaline cartilage with that of bone (Fig. 20 and Fig. 23).

Centers of Ossification.—In all bones ossification begins at one or more points called centers of ossification. The long bones usually have at least three centers, one for the shaft (*diaphysis*), one for each articular extremity (*epiphysis*), but besides these primary centers there are centers for the various processes.

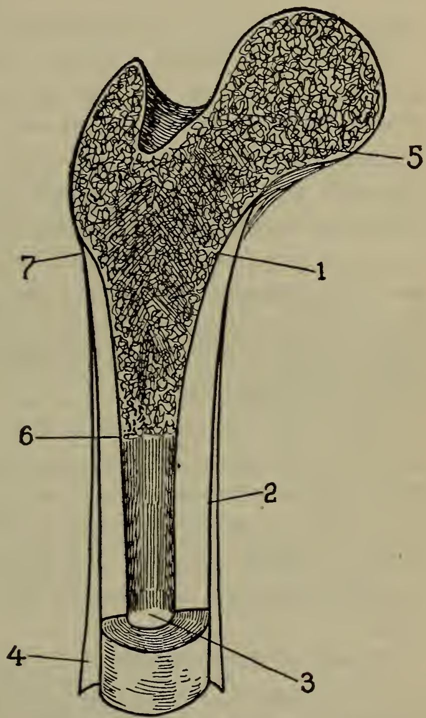


FIG. 109.—1. Head. 2. Shaft. 3. Medullary canal. 4. Periosteum. 5. Cancellous tissue or spongy bone. 6. Compact tissue. 7. Arches of cancellous tissue. (Brinckley, C. W. B.)

Articulations.—The union between two or more bones is called a *joint*, or *articulation*. These, as we have seen from the examination of the skeleton, are of great variety, making possible the varied movements of which the body is capable.

Structure of Joints.—The structure of the joint is dependent upon the kind and amount of motion it permits. In immovable joints, as that of the parietal bones, the bones are in close contact, being separated only by a thin layer of fibrous membrane (the *sutural ligament*).

In movable joints, as we have seen, the bones entering into the joint are expanded at the articulating end, the head of which is covered by a cap of cartilage called the *articular cartilage*. The surface to which cartilage is attached is called the *articular lamella*. In joints like that between the body of the vertebræ there is cartilage between the articulating surfaces, called the *interarticular cartilage*.

In the movable joints, the parts are bound by bands of tissue (*ligaments*) of various forms. In those joints in which firmness rather than motion is needed, the proportion of white fibrous tissue is greater; but when flexibility and elasticity as well as firmness are needed, the proportion of yellow elastic tissue is the greater, and in some cases the ligament consists entirely of yellow elastic tissue; as in the ligaments which hold the arches of the vertebræ. On the surface of the bone in movable joints there would be friction, and to prevent this the articulating surfaces are covered by a delicate membrane (*synovial*) of connective tissue with branched connective tissue corpuscles. This membrane secretes a thick, viscid, glary liquid, like the white of an egg, and is called *synovia*.

The synovial membranes are of three varieties: (1) *articular*, like that found in the movable joints; (2) *bursal*, where they are interposed between surfaces which move upon each other, as in the gliding of a tendon or a muscle; (3) *vaginal* (sheath synovial membrane), where tendons move through osseous or membranous canals, as in the flexor tendons.

Classes of Articulations.— Articulations may be grouped into three general classes: immovable (*synarthrosis*), mixed (*amphiarthrosis*), and movable (*diarthrosis*). For more important varieties of these classes, see diagram of the articulations.

DIAGRAM OF THE ARTICULATIONS.

(Modified from Gray's Anatomy.)

ARTICULATION.

- Articulations whose surfaces are connected by fibrous membranes or cartilage and without any synovial cavity, and permitting no motion (*Synarthrosis*).
  - By interlocking processes and indentations (*Sutura*).
    - Bone joining by indented edges (*Sutura vera*), as the parietal bones.
    - Bones joining by rough surfaces (*Sutura notha*), as the articulation between the parietal and squamous portion of the temporal bone.
  - The joining of a thin plate of one bone into the fissure of another (*Schindylesis*), as the articulation of the sphenoid with the vomer.
  - By the insertion of a conical process into a socket (*Gomphosis*), as the teeth in the alveolar process.
  - By contact of surfaces as in the epiphysis of a bone and its expanded portion (*Synchondrosis*), as in the inferior maxillary bone and in the epiphysis of the long bones.
- Mixed articulations with little motion (*Amphiarthrosis*).
  - Surfaces connected by fibrocartilage, no synovial membrane, limited motion (*Symphysis*), as the articulation of the bodies of the vertebræ.
  - Surfaces connected by an interosseous membrane (*Syndemosis*), as the articulation between the tibia and fibula.
- Free movement, well-developed synovial membrane (*Diarthrosis*).
  - Motion limited to two directions, forward and backward like that of a hinge (*Ginglymus*), as the articulation of the humerus and ulna.
  - By a pivot-process turning in a ring (*Trochoides*); the articulation of the radius with the ulna, and the odontoid process of the axis with the atlas.
  - By an ovoid head in an eliptical cavity, permitting movement in various directions, but no axial motion (*Condyloid*); wrist joint.
  - The concave surface of one bone fitting over the convex surface of another like a saddle (*Reciprocal Reception*); the joint between the carpal and metacarpal bones of the thumb.
  - Globular head of one bone received into the cup-shaped cavity of another (*Enarthrosis*); the head of the femur with acetabulum.
  - The articulating surfaces gliding on each other (*Arthrodia*); carpal and tarsal joints.

CHAPTER VII.

THE ALIMENTARY SYSTEM.

DISSECTION.

I. Kill a rat or cat with chloroform. (For method, see Appendix.)

II. Dissect the skin from the ventral portion. In the region of the neck look for, and observe: —

A. A body (one of the *salivary glands,* the *submaxillary*) (Fig. 119), close to the middle line of the submaxillary bone.

1. Observe shape, size, etc.
2. Lift up and trace the duct to its opening.

B. The large gland (*parotid*) (Fig. 119) situated in front of the ear and reaching to the angle of the jaw.

1. Observe as above.
2. Trace its duct.

C. Remove muscles, etc., covering the trachea (Fig. 5) and larynx. Cut away the front and side walls of the chest and abdomen, and remove the larynx, trachea, lungs, and heart. Observe: —

1. A slender muscular tube, noticing its relations and tracing its direction in the chest, and how it passes (Fig. 5) through the diaphragm.
2. The relation of the abdominal viscera (liver, stomach, etc.).

D. Turn the liver out of the way, and continue the tracing of the esophagus to stomach. Now observe carefully the stomach: —

1. Size, shape, position.
2. Its relation.
3. How supported?
4. The thin membrane attached to it and hanging down so as to cover up the other abdominal viscera. This membrane is called the *omentum,* and is a part of the peritoneum.

E. Now follow and carefully unravel the coils of the intestines, and as far as possible, spread out the delicate membrane (*mesentery*) which clings to them.

1. Look in the fat of the mesentery for blood vessels and lacteals.

2. Observe the termination of the small intestines.

3. Notice how the large intestines begin by a sac-like projection (*cæcum*). Do you find anything attached to the cœcum?

4. Observe the larger intestine on the other side. Cut away the front of the pelvis so as to trace it to its terminus. The lower portion of the intestine is the *rectum*. The portion between the cœcum and rectum is the *colon*.

5. Carefully note direction and relation of the intestines.

F. Spread out the portion of the mesentery lying in the concavity of the first coil (*duodenum*) of the small intestines.

1. Observe the branching glandular mass, *pancreas* (Fig. 6).

2. Notice relation.

3. Trace duct to its opening.

G. Examine large vein that enters the under side of the liver by several branches. Close by its side notice a duct (*gall duct*) formed by two main branches, and trace it to the small intestines.

H. Look for an elongated red body (*spleen*) (Fig. 6) just behind, and to the left of the stomach.

1. Has it a duct?

2. Are there any blood vessels going to it?

I. Tie the esophagus (Fig. 5) as high up as possible, and tie the rectum as low as possible. Then cut between the string and the body. Sever the mesenteric bands, etc., and also the other portions by which the canal is fixed. Remove the whole tube; cut away the mesentery; spread it out at full length.

1. Notice relative diameter and length of its various parts.

2. Length as compared with that of the animal.

J. Open the stomach.

1. Examine the orifices.

2. The mucous membrane. (Use a lens of ½-inch focus.)

Demonstrations. — 1. Obtain from your butcher two or three inches of the small intestine of a calf (just killed). Place in fifty per cent alcohol for twenty-four hours. Then open under water, and examine with lens of a magnifying

power of twenty or thirty diameters. What are the little papilla-like bodies?

2. Cut from the larger end of the stomach a piece about one half inch square. Wash for a few minutes in normal salt solution; with small pins fasten it to a piece of cork, putting muscular surface downward, and slightly stretching it. Pass it through sixty-, eighty-, and ninety-per-cent alcohol, leaving from one to two hours in each grade of alcohol. Color by keeping in hæmatoxylin for one or two days until well stained. After staining, remove to ninety-five-per-cent alcohol, in which it should remain until well hardened; then imbed, and make section, and mount as directed in the Appendix.

3. Take a similar piece from near the entrance of the stomach into the duodenum, and treat as above, and examine. What difference do you note in these two portions?

4. Cut off one or two inches of the duodenum and carefully wash by moving the piece back and forth in a normal salt solution, being careful not to injure the mucous membrane by undue pressure. Make cross-section of the pieces one-half inch long, and harden, stain, and mount as in experiment.

5. Carefully note: (*a*) the permanent folds (*valvulæ conniventes*), making partial rings around the interior of the intestine; (*b*) the prominent projecting hair-like processes (*villi*). Try to get both longitudinal and cross-section of the villi; (*c*) the glands (*crypts of Lieberkühn*) dipping into the mucous membrane; (*d*) the glands (*glands of Brunner*) in the submucous tissue; (*e*) the patches of granular-looking tissue (*solitary glands*); (*f*) muscular fibers (*muscularis mucosæ*) beneath the mucous membrane.

6. Examine in a similar way different parts of the small intestine. In what parts are the glands of Brunner most numerous? In what parts are they not found? Where are the solitary glands most numerous? Do you find the solitary gland sometimes occurring in patches (*Peyer's patches*)?

7. Examine in a similar way the larger intestine. Note difference in structure. Do you find the following in the larger intestine: villi, Peyer's patches, and valvulæ conniventes?

8. Take a small portion of a fresh liver, and tease out

in normal salt solution. Examine under high power, and note structure of the connective tissue and liver cells.

9. Macerate portions of the liver of the rabbit for four or five days in a two-per-cent solution of potassium dichromate and then in ninety-per-cent alcohol for one or two days. Stain in picrocarmine. Prepare a slide for examination, and examine under two-thirds and one-sixth objectives.

10. Inject the liver by means of the portal vein, using a carmine gelatin mass. Examine various sized sections of the liver. Make as thin a section as possible with a sharp razor in a moistened normal salt solution, and mount in glycerin, and examine with one-fourth objective.

11. Prepare as directed in Experiments 8 and 9 a portion of the pancreas and spleen, noting in each case the difference in structure.

12. Compare the structure of the salivary glands and pancreas. Also compare the structure of the parotid, sublingual, and submaxillary glands. These may be prepared as directed in Experiments 8 and 9.

13. Procure from the druggist a sheet of blue litmus paper and one of red litmus paper. Cut into strips one-fourth inch wide and two or three inches long. Put into a test-tube a few drops of sulphuric acid, and dilute with many times its own volume of water. Dip the end of a piece of blue litmus into the acid. Notice the change of color. In another test-tube put fifteen or twenty drops of ammonia diluted to several times its volume. Test this with a piece of red litmus paper. Notice change of color. When substances change blue litmus to red, they are said to be *acid;* and when they change the red to blue, they are called *alkaline.*

Test some distilled water (fresh rain water will do) with both red and blue litmus paper. Does it change the color of either? When substances do not affect either the blue or the red, it is called *neutral.*

Are the following acid, alkaline, or neutral? a solution of common salt, a solution of baking powder, a solution of wood ashes, a solution of sugar, the saliva, gastric juice, bile, vinegar, sour milk, and cream of tartar.

14. Collect eight or ten c.c. of saliva in a test-tube, and let stand until the turbidity has settled down into a sediment.

Add strong acetic acid until a stringy mass separates. Shake the tube gently, which will cause the stringy mass to form a lump, when it can be removed. The stringy mass is *mucin*.

15. Filter the liquid after you have removed the mucin, the precipitate left on the filter indicates the amount of proteids present in the saliva. Test some fresh saliva with Millon's reagent (see Appendix).

16. Add to some saliva in a test-tube a few drops of ferric chloride. See if the color disappears on the addition of a few drops of a solution of mercuric chloride (*corrosive sublimate*). The blood-red color is due to the presence of *potassium sulphocyanate* in the saliva.

17. Add to some saliva in a test-tube a few drops of a solution of silver nitrate (*lunar caustic*). A white precipitate indicates the presence of *chlorides* in the saliva.

18. Test the saliva for sodium and potassium (see Appendix).

19. Mount a section of the liver (fresh). Add by means of a pipette to the side of the cover glass a drop of strong iodine; the cells containing glycogen will be colored deep brown-red.

20. Macerate a piece of fresh liver in distilled water for five or six hours (having first washed the piece to remove the blood). Strain the solution through a clean cloth. To a small portion in a test-tube add a few drops of a solution of potassium iodide, and then a small amount of chlorine water. The port wine-red color produced is due to the *glycogen* in the first solution.

THE ALIMENTARY SYSTEM.—TEXT.

Need of Organs of Alimentation.—Food is needed to maintain the heat of the body, to furnish material for nervous and muscular activity and the various vital processes. Before it can get to the tissues where it is needed, it must get into the blood. Most of our food is not soluble, and before it can enter the blood it must be made so. To make the food soluble is the chief purpose of digestion, and the system of organs by which this is accomplished is the *alimentary canal, salivary glands, pancreas,* and *liver*.

Relation of the Alimentary Canal.—The tubular system is divided into five principal divisions, according to the func-

tions performed by the part: alimentation, respiration, circulation, secretion, and excretion.

Tissues of Alimentary Canal.— The principal tissues of this canal are muscular, connective, mucous, and in the abdominal cavity there is a fourth, the serous.

The Mucous Membrane.—This membrane lines the alimentary canal, the respiratory tract, the glands and tubes opening into the alimentary canal, and all other tubes communicating with the air.

The mucous membrane is in reality a modified skin reflected inward to line the various tubes which have external openings, and changed in its structure to adapt it to its new functions.

Like the skin, it is composed of two principal layers, the outer, or epithelial, whose cells are of various forms,—squamous (often arranged in several layers), cubical, columnar, and ciliated; and the inner, or corium, consisting of connective tissues, either simple, areolar, or containing a greater or less quantity of lymphoid tissue, and supplied with a dense network of capillaries. The mucous membrane is connected with organs which it lines by connective tissue, which is sometimes very abundant, forming a well-marked layer, called *submucous membrane.*

In the epithelium are imbedded litttle glands which secrete the fluid (*mucus*) which moistens the membrane. We shall notice that as the mucous membrane has new functions to perform, it becomes modified for its varied work.

The Mouth.—The alimentary canal begins with the mouth, or buccal cavity. The mouth is nearly oval in shape. It is bounded in front by the lips, on the sides by the cheeks, and possesses the upper and lower jaw, above by the hard palate, below by the tongue and mucous membrane, behind by the soft palate. The free border of the soft palate is called the *uvula*. Examine the mouth by the aid of a looking-glass. The opening from the mouth to the pharynx is called the *fauces*.

The Pharynx.—This (Fig. 111) is the cavity just back of the mouth and nasal passages. It is four inches in length, extending from the under surface of the skull to the space between the fifth and sixth cervical vertebræ. It has seven openings:—

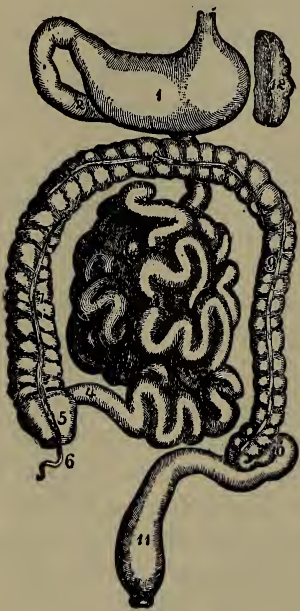


FIG. 110.—THE ALIMENTARY CANAL.

1. Stomach. 2. Duodenum (beginning of small intestines). 3. Small intestines. 4. Ileum (last portion of small intestines). 5. Cæcum. 6. Vermiform appendix. 7. Ascending colon. 8. Transverse colon. 9. Descending colon. 10. Sigmoid flexure. 11. Rectum. 5, 7, 8, 9, 10, and 11. Large intestines. 12. Spleen.

1. Two from the nasal passages — *posterior nares.*
2. Two to the ears — *Eustachian tubes.*
3. One to the mouth—*fauces.*
4. One to the larynx—*glottis.*
5. One to the esophagus — below.

It has three coats, the outer muscular, consisting of two sets of fibers, longitudinal and transverse; a middle fibrous, and an inner mucous. The mucous membrane is covered as low down as the floor of the nares with ciliated epithelium.

The Tonsils. — These are two oval bodies situated in the spaces between the anterior and posterior pillars of the fauces. Each tonsil consists of a mass of lymphoid tissue. The free surface is covered with stratified epithelium, perforated by twelve to fifteen orifices, which lead into small cavities, or crypts, from which branches go out into the substance of the gland. In these follicles, or branches, active multiplication of lymph cells occurs, which pass through into crypts, and mingle with the saliva as salivary corpuscles.

This viscid secretion aids in deglutition by lubricating the bolus of food as it passes in the second stage of the act of deglutition.

The Esophagus, or Gullet.— This is the continuation of the pharynx, and extends to the stomach, being in length about nine inches. It lies in front of the spine and back of the trachea, its general direction being vertical. Its coats are similar to those of the pharynx. There is, however, a marked modification in the mucous membrane, the little glands secreting an oily fluid (*esophageal*). They are most numerous in the lower part of the tube.

The Stomach. — Before reaching the stomach, the esophagus passes through the diaphragm. It terminates at the *cardiac orifice.* At this point the alimentary canal becomes very much enlarged into a pouch-like organ (*stomach*).

FIG. 111.— THE PHARYNX. (From Yaggy's Anatomical Study.)

1. Upper part of pharynx. 2. Opening of the Eustachian tube. 3. Soft palate. 4. Fauces. 5. Epiglottis. 6. Glottis. 7. Esophagus. 8. Trachea. 9. Posterior nares. 10. Nasal fossa. 11. Base of cranium.

This is situated in the upper and left side of the ventral cavity, below the liver, and above the transverse colon.

Its shape resembles that of a bagpipe, having the greater curve below, and the larger end (*splenic*), or *fundus,* to the left, and the smaller (*pyloric*), or *antrum,* to the right.

The size varies with the individual and the degree of distension; when moderately distended, the transverse diameter is about twelve inches.

Openings of the Stomach.—They are the esophageal, or *cardiac,* and the intestinal, or *pyloric.* At the latter orifice the oblique muscular fibers interlace from different directions, forming a kind of sphincter muscle, and with the mucous membrane form a kind of valve.

The coats are four: Serous (derived from the peritoneum), muscular, areolar (or submucous), and mucous.

Serous Membranes.—These membranes differ from the mucous membranes both in structure and function.

Very generally they are closed sacs with one portion attached to the walls of the cavity they line, and the other reflected over the organ or organs contained in the cavity, so placed between and over the organs that they may move upon each other without friction. These membranes are thin, transparent, glistening; lined on their inner surface by a single layer of endothelial cells, supported upon a matrix of fibrous connective tissue, with network of fine elastic fibers. They secrete a fluid very closely resembling lymph. Such is the membrane (*peritoneum*) which lines the abdominal cavity and forms the serous coats of its viscera (Fig. 113).

Muscular Coat of Stomach.—This coat lies just beneath the serous. It consists of three layers—the outer of longitudinal fibers, the middle of circular or transverse fibers, which are more numerous at the pyloric end, and the oblique, found chiefly at the cardiac portion. The muscles are more strongly developed in the antrum than in the fundus.

Sub-Mucous Coat.—This membrane lies between the muscular and mucous coats, and forms their connection. It is highly vascular; i. e., having a large number of blood vessels.

Mucous Coat of Stomach.—This is the inner lining of the stomach. It is smooth, velvety, and of a pinkish tint. It rests upon a layer of loose cellular tissue (the *submucous tissue*), and is smooth, soft, and velvety, of a pale pink color, and when the process of digestion is not going on, is thrown into numerous folds, or *rugæ,* which dis-

appear when the stomach is distended, as in the act of digestion. A fine connective tissue forms the basis of the mucous membrane, resembling in its structure adenoid tissue, and in which is supported the tubular glands. In various parts of this coat, just beneath the glands, are masses of adenoid tissue, called lymphoid follicles. In the deepest part of the mucous membrane is a layer of circular and longitudinal unstriped muscular fibers, known as the *muscularis mucosæ*, separating the mucous membrane from the submucous.

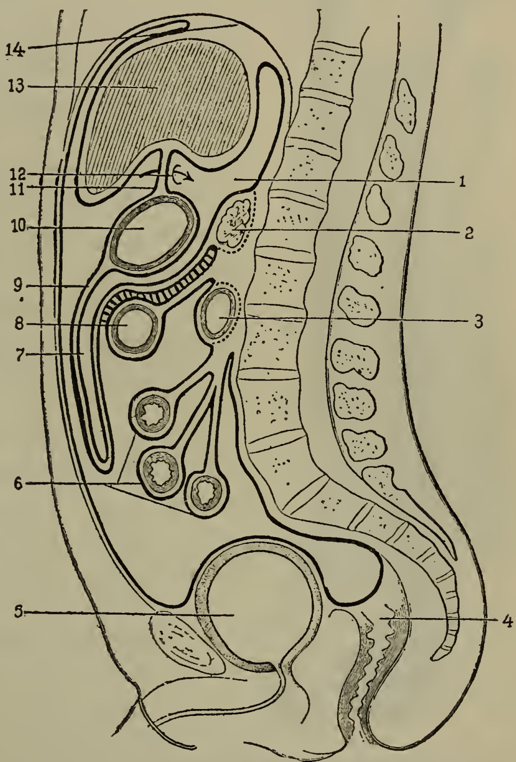


FIG. 112.—THE PERITONEUM.

1. Bursa of the omentum. 2. Pancreas. 3. Duodenum. 4. Rectum. 5. Bladder. 6. Small intestines. 7. Omental sac. 8. Transverse colon. 9. Greater omentum. 10. Stomach. 11. Lesser omentum. 12. Foramen of Winslow (epiloicum). 13. Liver. 14. Diaphragm.

On examination by a low-power lens, the mucous membrane of the stomach presents a honeycomb appearance, produced by shallow depressions of one two-hundredth to one three-hundred-and-fiftieth of an inch in diameter, but near the pylorus they are larger, being one one-hundredth of an inch. These depressions (*alveoli*) are separated by slightly elevated ridges, which sometimes, in morbid conditions, bear minute vascular processes, resem-

bling vilii. Leading into these alveoli from below are tubular glands, of which there are two varieties, (1) *cardiac* and (2) *pyloric.*

FIG. 113.—VERTICAL SECTION OF MUCOUS MEMBRANE OF THE CARDIAC END OF STOMACH.

a. Duct of cardiac gland with columnar epithelium becoming shorter as the cells are traced downward. *n.* Neck of gland tubes with central and parietal or so-called peptic cells. *b.* Fundus with curved cæcal extremity — the parietal cells are not so numerous here. X 400. (Klein and Noble Smith.)

Cardiac Glands (Fig. 113) are found throughout the entire cardiac portion of the stomach. They are arranged in groups of four or five, the groups being separated by a fine connective tissue. They consist of a duct (*alveola*), which forms about one sixth the length of the gland, and into which open two or three tubes.

The duct is lined with columnar epithelium. The gland proper, or the portion below the duct, consists of the upper third, the neck, and the lower two thirds, the body. The narrow neck is lined with granular cubical cells, which are continuous with the columnar cells of the duct. Between these cells and the membrane proper (Fig. 113) there are large oval granular cells, each with a prominent nucleus, called *parietal cells.*

The body of the gland is wider than the neck, and ends in a rounded expansion, or *fundus,* which terminates near the muscularis mucosæ. The structure of the gland changes as it approaches the pylorus, the ducts become

longer, and the tube proper becomes shorter, with occasional branches of the fundus of the body.

Pyloric Glands.— These (Fig. 114) are situated in the pyloric portion of the stomach. Their ducts are longer; the tubes which open into the ducts have very short necks (generally two or three in number). The cells lining these glands are similar to those of the cardiac, with the exception that they have no parietal cells. As the glands near the pyloric orifice, they become more convoluted and deeply seated, becoming continuous with the glands of Brunner of the duodenum.

Lymphatics.—These surround the gland tube to a greater or less extent. Near the fundus of the peptic glands are found masses of lymphoid tissue, resembling the solitary glands of the intestines, and which form distinct follicles.

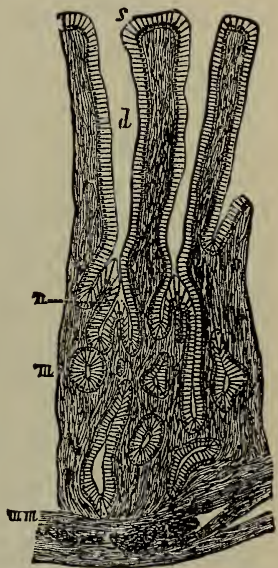


FIG. 114.—VERTICAL SECTION THROUGH PYLORIC GLANDS.
s. Free surface. *d.* Duct of pyloric gland. *n.* Neck of the gland. *m.* The gland alveoli. *m. m.* Muscularis mucosæ. (Klein and Noblė Smith.)

Blood Vessels.— These find their way to the mucous membrane by way of the submucous, in which they send branches upward between the closely packed gland tubes, anastomosing around them by means of a fine capillary network with oblong meshes.

Around the orifices of the tubes is a dense network of larger capillaries, which is continuous with the deeper plexus just described. It is from this superficial network that the veins chiefly take their origin.

Nerves.— These (Fig. 115) are derived from the branches of the pneumogastric and sympathetic, forming plexuses in the submucous and muscular coats, containing numerous ganglia. Study Fig. 115 carefully.

The Intestines.— At the pyloric orifice the alimentary canal becomes contracted into a long tube (*intestines*), about

twenty-five feet in length, divided into two portions distinguished according to size, large and small.

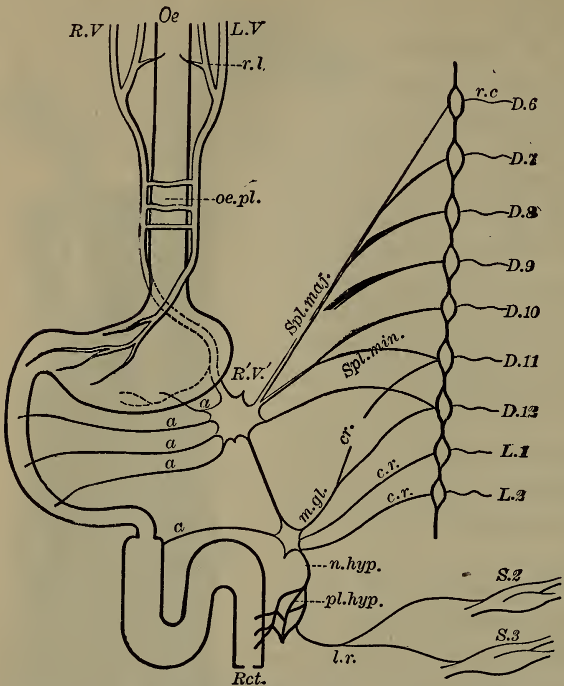


Fig. 115. — Diagram of the Nerves of the Alimentary Canal in the Dog.[1]

Oe to *Rct.* Alimentary canal. *L. V.* Left vagus nerve ending in front of the stomach. *r. l.* Recurrent laryngeal nerve supplying the upper part of the esophagus. *R. V.* Right vagus joining the left vagus in the esophageal plexus, *oe. pl,* and passing down to supply the posterior part of the stomach and continuing as the *R.′ V.′* to join the solar plexus, represented in the figure as a single ganglion and connected with the inferior mesenteric ganglion (or plexus). *a.* Branches of solar plexus to stomach and small intestines. *Spl. maj.* Larger splanchnic from the thoracic ganglia and the rami communicantes, *r. c.* of the 6th to 9th dorsal nerves. *Spl. min.* Smaller splanchnic nerve from the 10th and the 11th dorsal nerve. The larger and smaller splanchnics both join the solar plexus, from which they pass to the alimentary canal. *c. r.* Nerves from the ganglia of the 11th and the 12th dorsal and the 1st and 2d lumbar nerves. These nerves join the mesenteric ganglia from which they pass by the hypogastric nerve and the hypogastric plexus to the circular muscle of the rectum. *n. hyp.* Hypogastric nerve. *pl. hyp.* Hypogastric plexus. *l. r.* Nerves from the 2d and 3d sacral nerves, *S. 2, S 3* (*nervi erigentes*), passing by the hypogastric plexus to the longitudinal muscles of the rectum.

Coats of the Smaller Intestines. —These like the stomach, have four coats — the serous, muscular, submucous, and mucous.

Serous Coat. —This is derived from the reflection of the peritoneum encircling it, as represented in Fig. 112, so as to leave an opening through which the blood vessels enter.

Muscular Coats. —These consist of an internal, circular, and an external

[1] "It was not observed until too late that in the diagram of the nerves of the alimentary canal in the dog, *twelve* dorsal nerves had been represented. The figure makes no pretense to anatomical exactness; but it would have been better to represent either thirteen or fifteen dorsal nerves."—*Foster.*

layer of longitudinal fibers, of which the former is usually the thicker. They are provided with lymphatic vessels, which form an independent system from that of the mucous membrane. Between these muscular coats is a nerve plexus (*plexus of Auerbach*).

Submucous Coat.— The coat lies just beneath the mucous coat, and is similar to that described in the stomach. It is provided with numerous blood vessels and lymphatics. In it there is a fine plexus, consisting principally of non-medullated fibers, having ganglia at the nodal points, forming the *plexus of Meissner*. This plexus of nerves is found in the submucous membrane, from the stomach to the end of the large intestines.

Mucous Membrane.— In no part of the alimentary tract does the mucous membrane have so varied a function to perform as in the intestines, and we find it, for this reason, much more complex or modified. In general structure it resembles that of the stomach, having in its deeper part two layers of muscular fibers, circular and longitudinal, forming the *muscularis mucosæ.*

The mucous membrane is thrown into permanent folds, called *valvulæ conniventes*. These begin in the duodenum about two inches from the pylorus, become larger and more numerous just beyond the entrance of the bile duct, and are thickly arranged and well developed throughout the jejunum; then they gradually diminish in size and number, and cease near the middle of the ileum. They are formed by the doubling inward of the mucous membrane so as to form crescent-shaped folds, each individual fold not extending more than two thirds around the circumference of the wall. To get a proper idea of these, it is best to prepare a portion of the intestine, as directed in the experiments.

These permanent folds serve two very important functions: (1) They increase the surface of the mucous membrane for absorption and secretion; (2) they retard the passage of the liquid contents of the intestines.

Glands.— These are of three principal varieties, the crypts of Lieberkühn, glands of Brunner, and glands of Peyer.

The crypts of Lieberkühn, or intestinal follicles, are simple tubular depressions in the mucous membrane, and are thickly distributed over the whole surface of both the small and large intestine. In the small intestine they are visible only by means of a low-power lens; they are large in the large intestines, and increase in size as they near the end of the intestine; in the rectum the openings are visible to the naked eye. They vary in length from one one-hundred-and-eightieth to one sixtieth of an inch. The mucous membrane by which they are lined is essentially like that of the intestinal membrane, but having numerous goblet cells.

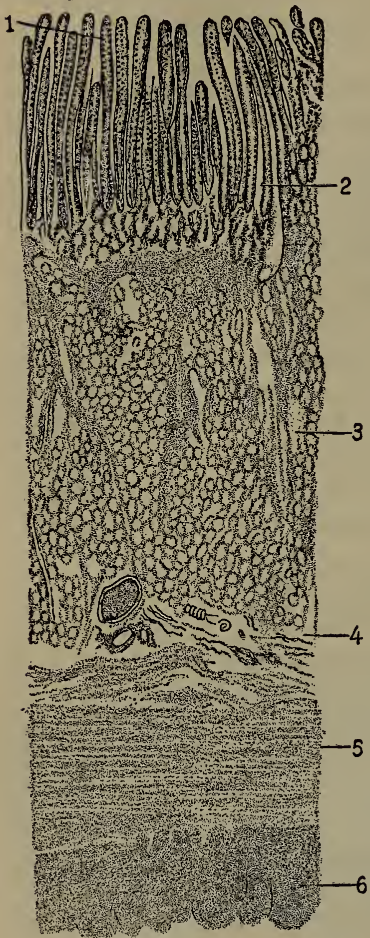


FIG. 116.—MUCOUS MEMBRANE OF SMALL INTESTINES.

1, 2, 3. Mucous membrane. 1. Villi. 2. Intestinal gland (crypts of Lieberkühn). 3. Duodenal glands. 4. Submucous membrane. 5. Muscular coat. 6. Serous coat.

The Glands of Brunner.—These are found only in the duodenum, at the commencement of which they are thickly set, and diminish gradually along the course of the duodenum. They are situated beneath the muscularis mucosæ, imbedded in the submucous tissue. Each gland consists of a branched and convoluted tube, resembling in structure the pyloric glands, and like them they go through a similar change during secretion, but they are more convoluted, and have longer ducts.

The Glands of Peyer.—These are found principally in the small intestine, and are most numerous near the ileo-cæcal valve. They are of two forms — single (*glandulæ solitariæ*), sometimes called solitary glands, and in groups, called *Peyer's patches.* They are of oval form, about one-half inch in diameter, their longer axis longitudinal.

In structure they consist of single or aggregated masses of adenoid tissue, forming lymph follicles. Each gland is from one twenty-fourth to one twelfth of an inch in diameter. The glands are most numerous in the submucous coat, but sometimes they project through the muscularis mucosæ into the mucous membrane. In case of the agminate glands, each follicle reaches the free surface of the intestines, and is covered with columnar epithelium. Openings of the crypts surround each gland.

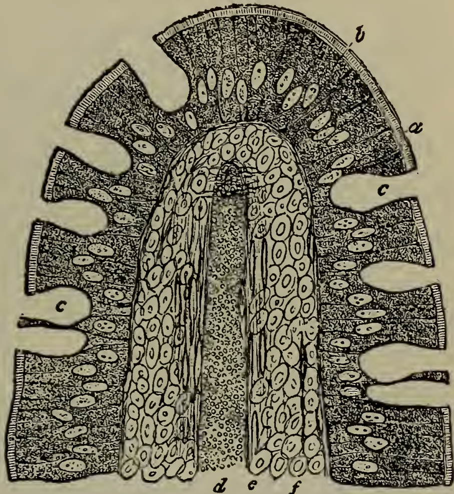


Fig. 117. — Vertical Section of a Villus.
a. Striated basilar epithelium. *b.* Columnar epithelium. *c.* Goblet cells. *d.* Central lymph vessel. *e.* Smooth muscular fiber (involuntary). *f.* Adenoid stroma of villus containing lymph corpuscles. (After Sanderson.)

Peyer's patches are most prominent and larger in children and young persons.

The Villi.— These (Fig. 117) are found only in the mucous membrane of the small intestines. They are vascular, varying from one forty-eighth to one eighth of an inch in length, covering the mucous membrane, giving to it a velvety appearance. According to Krause, there are from fifty to ninety to the square line in the upper part of the intestines, and forty to seventy to the same area in the lower part. They

vary in form, just as the lymphatics they receive are empty or full.

Each villus consists of a small projection of mucous membrane, supported on its interior by fine adenoid tissue, forming a framework, or stroma, in which the other constituents are contained.

The mucous membrane which covers the villus is made up of columnar epithelium, which rests on a fine basement membrane, beneath which are blood vessels, fibers of the muscularis mucosæ, a single lymphatic, or lacteal vessel, which is rarely looped or branched (Fig. 118). The cells are arranged radially, and contain numerous goblet cells.

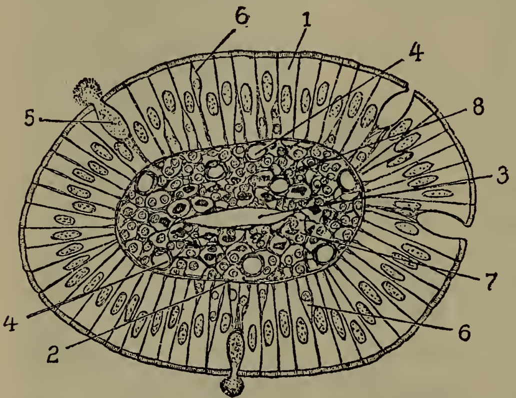


FIG. 118.—CROSS-SECTION OF A VILLUS.
1. Columnar epithelium. 2. Basement membrane. 3. Central lacteal. 4. Blood capillary. 5. Goblet cell. 6. Lymph corpuscles between epithelial cells. 7. Section of involuntary muscle fiber. 8. Adenoid tissue.

The muscularis mucosæ is arranged into a hollow cone immediately around the central lacteal, and is thus beneath the blood vessels, and by contraction aids in forcing the chyle into the lacteals. If the lacteals have valves, what would be the effects of the pressure from the contraction of the muscle fiber of the muscular layer around the lacteal? These tubes make up the system vessels, called *lacteals,* and are but modified lymphatic vessels, whose purpose is to absorb and carry the chyle to the thoracic duct.

The Large Intestine.— This forms the remainder of the alimentary canal, is about five feet long, and varies in diameter from one and one-half to two and one-half inches. It consists of the following portions: The portion below the entrance of the small intestine, with its appendix (*vermi-*

form appendix), the cœcum; the terminal portion, the *rectum;* the portion between these parts, the *colon.*

The colon is the longest part. It begins on the right of the abdomen, extends upward (*ascending colon*), across (*transverse colon*), and then downward on the left side (*descending colon*), where it makes an S-shaped bend (*sigmoid flexure*), below which the rectum begins, completing the larger intestines.

At the union of the large and small intestines is found a valve (*ilio-cœcal*), formed by two flaps of mucous membrane sloping downward into the colon, and so arranged as to permit bodies to pass readily from the ileum to the colon, but not in the other way.

The mucous coat of the large intestine is like that of the small, except that the mucous membrane has no villi nor valvulæ conniventes, nor Peyer's patches.

It has follicles and glands much like those of the small intestines.

The muscular coat consists of an external longitudinal and an internal circular layer. The former is partly collected into three flat longitudinal bands, between which the longitudinal layer, while present, is very thin, and being shorter than the walls to which they are attached, form *sacculi.* The circular fibers form thin, continuous layers, being more numerous in the construction of the sacculi, and form in the rectum the internal sphincter.

ACCESSORY ORGANS.

The Salivary Glands.— There is need of other fluids in the process of digestion than those secreted by the alimentary canal. To supply this need, there are organs connecting with the alimentary canal, by which the needed fluids are made. In general, their structure is that of a complex system of minute tubes lined with mucous membrane.

Opening into the mouth are the *salivary glands.* There are three pairs of these organs: the *parotid,* situated just in front of the ears, its ducts (*Stenson's duct*) opening inside

the cheek, opposite the second upper molar tooth; the *sub-maxillary*, between the two halves of the lower jaw, its duct (*Wharton's duct*) opening beneath the tongue; the *sublingual* (see Fig. 120), which lies beneath the mucous membrane of the floor of the mouth, close to the symphysis — its ducts are called *ducts of Rivinus.*

There are three varieties of salivary glands, according to the nature of their secretion.

I. *True salivary glands,* as the parotid, with small alveolar lumen; the cells lining the tubule are short, granular, columnar cells.

II. *True mucus-secreting glands,* as the sublingual, with larger tubules, and larger lumen, and larger lining cells. In these we find two kinds of cells — (1) *mucous, or central cells,* which are transparent columnar cells, having irregular or flattened nuclei; (2) *crescents of Gianuzzi*—these are parietal cells of crescent shape, distributed at intervals between the central cells of the basement membrane.

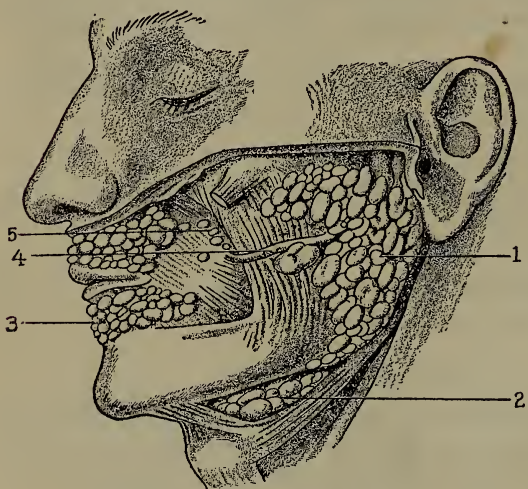


FIG. 119.—SALIVARY GLANDS.
1. Parotid gland. 2. Submaxillary gland. 3. Labial glands. 4. Duct of parotid gland. 5. Buccal glands.

III. *Muco-salivary,* or *mixed glands,* as the submaxillary, which have part of the glands, like that of the mucous gland, and the rest like that of the salivary glands proper.

The Liver.—The liver (Fig. 121) is the largest gland of the body. Its position is in the upper part of the abdomen,

more on the right than the left, just below the diaphragm. It is of a dark, reddish-brown color, and of soft, pliable texture.

The ducts from each half of the liver unite to form *hepatic ducts.* These unite with the *cystic duct,* and the common duct thus formed enters the duodenum about four inches from the pylorus.

The liver is a highly vascular organ, and receives its blood supply from two distinct sources — (1) the hepatic artery; (2) the portal veins. The hepatic artery brings blood to the organ, which, together with the blood from the portal veins, is returned to the vena cava by the hepatic vein.

The liver is covered incompletely by the peritoneum; beneath this covering, on the entire surface of the liver, is a very fine coat of connective tissue (areolar tissue). The connective tissue is the thickest where the peritoneum does not cover the liver, and invests the lobules with an almost imperceptible layer of connective tissue. This tissue at the transverse fissure is merged into the connective tissue investment, called the *capsule of Glisson,* which invests the portal vein, hepatic artery, and the hepatic duct as they enter the liver at this part, and accompanies them in their branches through the substance of the liver.

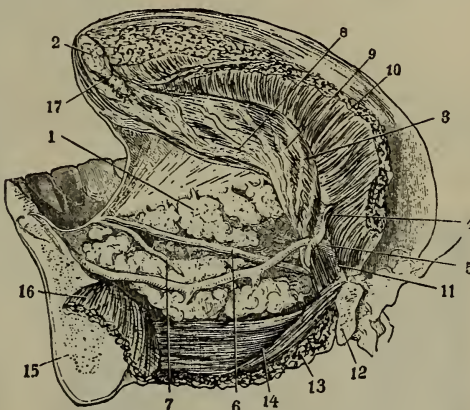


FIG. 120. — SUBLINGUAL GLAND.
1. Sublingual gland. 2. Glands of the top of the tongue. 3. Lingual nerve. 4. Hypoglossal nerve. 5. Sublingual artery. 6. Duct of submaxillary gland 7. Duct of sublingual gland. 8. Styloglossus muscle. 9. Lingual. 10. Genio-glossus. 11. Hypoglossal. 12. Cut end of hyoid bone. 13. Mylo-hyoid. 14. Genio-hyoid. 15. Cut end of inferior maxillary. 16. Genio-glossus. 17. Transverse ligament.

The liver is made up of small roundish or oval portions, called lobules, which have a diameter of one twentieth to

one tenth of an inch, and are made up of minute branches, of the portal veins, hepatic artery, hepatic vein, and hepatic

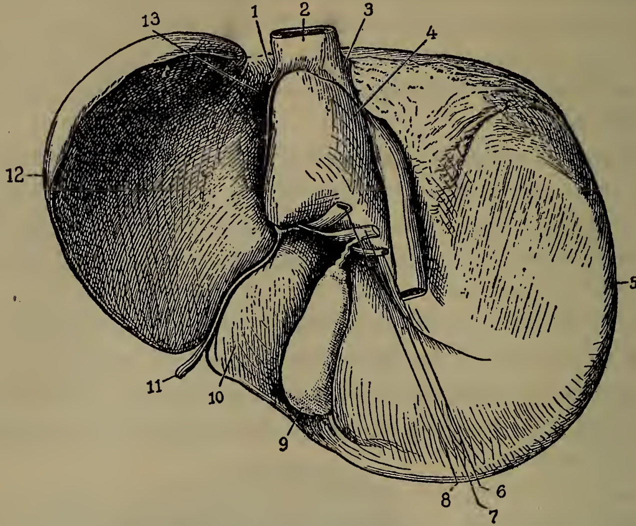


FIG. 121.—THE LIVER. SEEN FROM THE BACK AND LOWER SURFACES.
1. Hepatic vein. 2. Vena cava inferior. 3. Hepatic vein. 4. Caudate lobe. 5. Right lobe. 6. Hepatic artery. 7. Hepatic duct. 8. Portal vein. 9. Gall cyst. 10. Quadrate lobe. 11. Ligamentum teres. 12. Left lobe. 13. Ligamentum venosum.

cells (Fig. 123). The cells become somewhat polyhedral in form from mutual pressure. They are from one one thousandth to one eight hundredth of an inch in diameter, having one or more prominent nuclei.

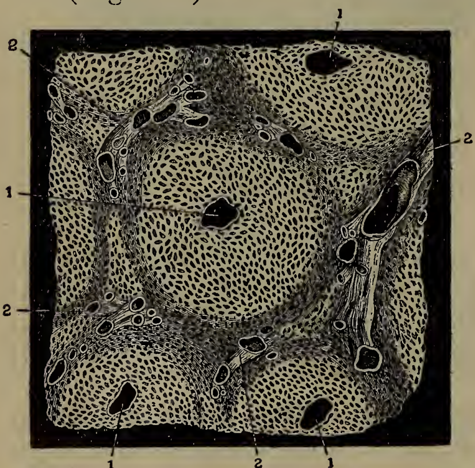


FIG. 122.—LOBULE OF LIVER.
1. Central vein. 2. Peripheral, or interlobular, veins.

In their cell substance are found numerous fatty molecules, possibly some granules of bile pigment, and a vis-

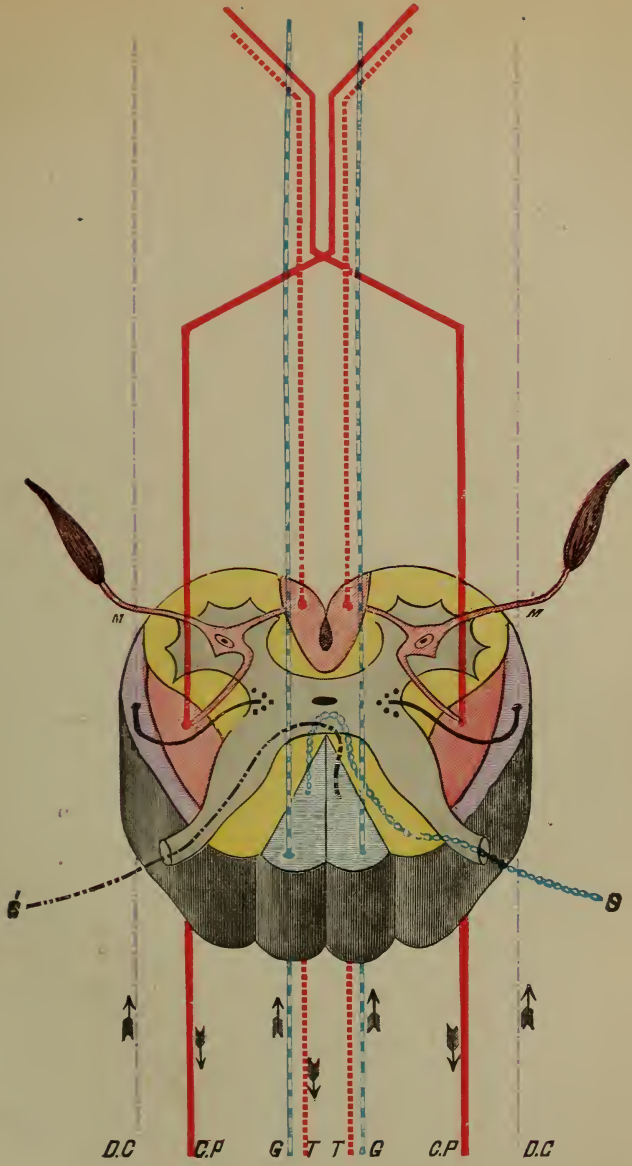


PLATE VIII.

FIG. 71.—A DIAGRAM DESIGNED TO ILLUSTRATE THE CONNECTIONS OF THE MOTOR AND SENSORY CONDUCTING TRACTS OF THE CORD WITH THE SPINAL NERVES.

(Modified from Bramwell.) (From Ranney.)

M. Motor fibers of the anterior root of a spinal nerve. *S*, *S'*. Sensory fibers of the posterior root. Note that the course of *S* and *S'* are not the same. Some sensory fibers pass directly through the posterior horn of the spinal gray substance, and others through Burdach's column to reach the gray substance. The direct cerebellar column is composed of fibers which start in Clarke's column of cells. The fibers of the two pyramidal tracts become united to the motor cells in the anterior horns of the spinal gray substance.

ible amount of glycogen. They sometimes exhibit a slow amœboid movement. They are supported by a very delicate tissue, continuous with the interlobular connective tissue.

The arrangement of the blood vessels of the liver is very complex. The portal vein in its course gives off small branches, which divide and subdivide between the lobules, limiting them in forming the interlobular veins. From these *interlobular* veins is given off a dense capillary network, which is prolonged into the substance of the lobule, and these capillaries re-collect to form a vein in the center of the lobule, called the *intralobular vein;* the intercellular spaces give rise to the bile capillaries, which unite to form the hepatic ducts.

The Secretion of the Bile.— The secretion of the bile is going on constantly, but is accelerated on taking food, and retarded during fasting. The bile is formed in the hepatic cells, and discharged into the minute hepatic ducts, and from these into the main hepatic ducts, and may be carried at once into the duodenum. This probably only takes place during digestion; i. e., for three to five hours after food is taken. When it is not needed for digestion, it regurgitates from the common bile duct, through the cystic duct, into the gall bladder, where it accumulates till it is needed for the next period of digestion, when it is discharged into the intestine.

FIG. 123.—HEPATIC CELLS. LIVER OF CAT. (Brinckley, C. W. B.)

The intralobular veins discharge their contents into veins called *sublobular* veins (Fig. 122), which unite to form the main branches of the hepatic veins, which in turn leave the posterior border of the liver to form two or three principal trunks, which empty into the superior vena cava. The sub-

lobular and hepatic veins have little or no connective tissue around them, and their walls being very thin, form mere channels in the substance of the liver. The hepatic artery is distributed similar to that of the portal vein, its blood being returned by small branches either into the ramification of the portal veins or into the capillary plexus of the lobules which connect the interlobular and the intralobular veins. The chief function of the hepatic vein is to distribute blood for the nutrition of the capsule of Glisson to the walls of the ducts and blood vessels, and to other parts of the liver. The hepatic duct has a distribution and division similar to that of the portal vein. It has its origin in the minute passages between the cells of the lobule, and forms bile capillaries.

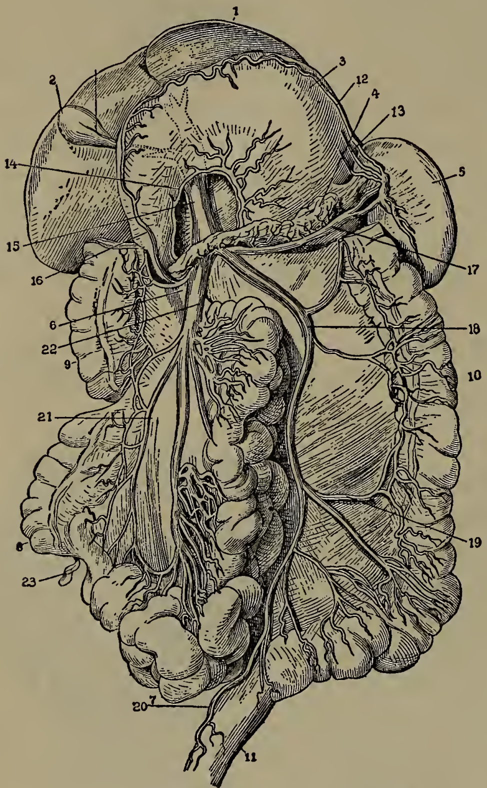


FIG. 124. — THE PORTAL CIRCULATION.

1. Liver. 2. Gall cyst. 3. Posterior surface of stomach. 4. Pancreas. 5. Spleen. 6. Duodenum. 7. Small intestine. 8. Cæcum. 9. Ascending colon (right). 10. Descending colon (left). 11. Rectum. 12. Left gastroepiloic vein. 13. Short gastric vein. 14. Coronary vein. 15. Portal vein. 16. Right gastro-epiloic vein. 17. Splenic vein. 18. Inferior mesenteric vein. 19. Left colic vein. 20. Superior hemorrhoidal. 21. Right colic vein. 22. Superior mesenteric vein.

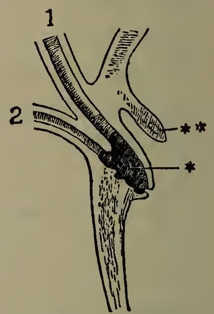


FIG. 125. — OPENING OF DUCT FROM THE LIVER AND THE PANCREAS.

1. Hepatic duct. 2. Pancreatic duct.

Fat Digestion.— As has been stated, the purpose of digestion is to render the food soluble. Fats may be made soluble in two ways: (1) by making them into emulsion, (2) by converting them into soaps.

The first of these processes is purely physical, simply being the division of the oil into microscopic drops; and the smaller the drops the more complete the emulsion.

The emulsion is formed more readily when the fats are old, and contain a free acid, and in the presence of an alkali. Milk is an example of an emulsion.

The second process is a chemical one. Most of the common fats are produced by treating glycerin with an acid (called *fat acids*), as *palmitic acid, stearitic acid, oleic acid.*

Glycerin + Palmitic Acid = Palmitin (fat) + water.

Glycerin + Stearitic Acid = Stearin (fat) + water.

Glycerin + Oleic Acid = Olein (fat) + water.

Glycerin belongs to a class of bodies called alcohols, which in the presence of acid act as bases, producing salts, so that fats are called salts (*ethereal salts*).

A can of nitroglycerin and a can of lard are closely related.

Glycerin + Nitric Acid = Nitroglycerin + water.

Glycerin + Palmitic Acid = Palmitin + water.

When a fat is treated with an alkali, the metal of the alkali displaces the glycerin radical, and gives a metal salt of the acid and glycerin. The salt produced by the alkali joining with the fat acid is called a *soap,* and the process by which the fat is decomposed is called saponification.

Palmitin + Alkali (Caustic Soda) = Soap (Sodium Palmate) + Glycerin.

Palmitin + Alkali (Caustic Potash) = Soap (Potassium Palmate) + Glycerin.

Sodium alkalies give hard soaps; potash alkalies give soft soaps.

We can now see a reason for the alkaline nature of the bile and pancreatic juices; but as the alkaline nature of the intestinal juices is not very great, so there is only a small

part of the fats converted into soaps, and it is now thought the function of these is to assist in the emulsification of the fats.

The Gall Bladder.— This is a pear-shaped bag (Fig. 124), situated under the right lobe of the liver, with its larger end projecting beyond the front margin of the liver,

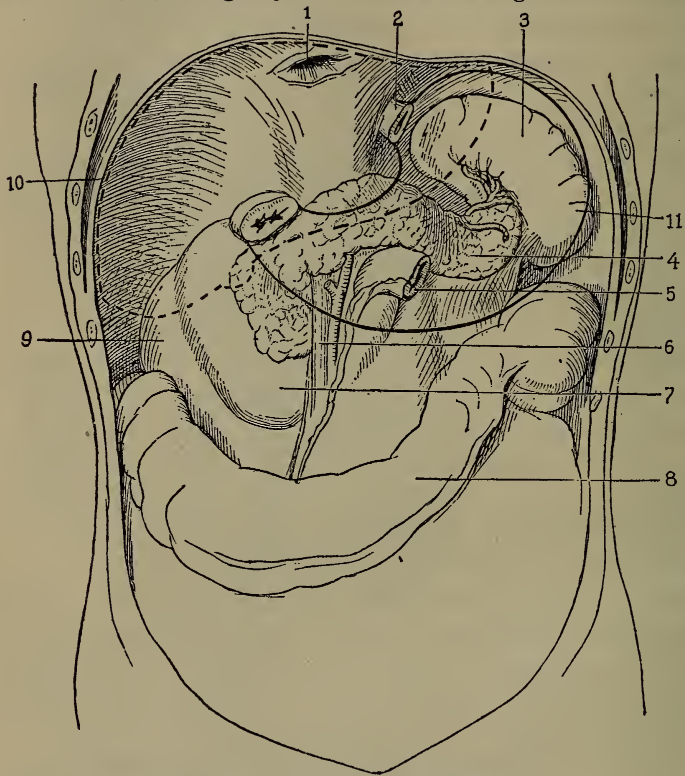


FIG. 126.—THE PANCREAS AND SPLEEN.

1. Vena cava. 2. Esophagus. 3. Spleen. 4. Pancreas. 5. Duodenum. 6. Superior mesenteric vein. 7. Small intestine. 8. Transverse colon. 9. Right Kidney. 10. Dotted line shows outline of the liver. 11. Deep black line gives outline of the stomach.

and its smaller portion contracting into the cystic duct. It lies below the peritoneum, by which it is supported. It is about four inches long, and one inch broad at its widest part. It has three principal coats: an external, serous; a middle, fibrous (areolar), containing plain muscular fibers; and

internal, mucous, with columnar epithelium. To the naked eye the mucous membrane presents the appearance of honeycomb. The mucous membrane of the duct is raised up in crescent folds, which together appear like a spiral valve, and aid in the retention of the bile during the interval of digestion. The mucous glands of the body of the organ and ducts secrete a viscid mucus.

The Pancreas.—This organ (Fig. 126) lies transversely across the abdominal cavity, opposite the first lumbar vertebra, back of the stomach. It is elongated, somewhat triangular in form, the larger end being embraced by the curve of the duodenum. It is of pinkish color, soft texture, and in general structure like the salivary glands. It is invested by a thin connective tissue capsule, which sends off divisions, or septa, between the lobules, along which the nerves and blood vessels find their way to the substance of the gland. The main duct begins at the narrow end by the union of the ducts from the lobules of this part, and, running the whole length of the gland, receives in its course contributing ducts from the lobules, the ducts joining the main one at nearly right angles. Its duct (*canal of Wirsung*) enters the duodenum obliquely, forming, with the bile duct (*ductus communis choledochus*), a common duct. While the ducts seem to unite, their union is not complete, as they do not mingle their contents until after they enter the wall of the duodenum, the ducts being separated by a septum (Fig. 125).

The gland is of the compound racemose variety, but its acini are more tubular and numerous than the salivary glands. It is about six inches long, one and a half inches wide, and one inch thick.

THE SPLEEN.

The spleen (Fig. 126) is situated to the left of the stomach, between it and the diaphragm; is of deep red color, of variable shape and size, being generally oval, somewhat concavo-convex. It is the largest of the so-called vascular organs. Its vessels enter and leave the gland at the inner side of hilus.

Structure.— It is almost entirely covered by a serous coat, derived from the peritoneum. It has beneath this coat a covering of connective tissue, which forms its true capsule, and which sends off prolongation *trabeculæ* into the substance of the organ, which branch and anastomose to form a supporting framework, or *stroma,* and in the meshes of which is held the proper substance, the spleen (*spleen-pulp*). In the capsule, the proportion of elastic fibers predominate, and mingle with the unstriated muscular tissue. These elements enter into the make-up of the trabeculæ. It has a large supply of blood vessels.

Functions.— Its more important functions are: (1) To store up some of the changed and absorbed proteid food, that it may be gradually introduced into the blood, as demanded by the general system. This is supported by the fact that the spleen gradually increases in size during the digestive process, and from the larger amount of fine granular albuminous plasma in its parenchyma; (2) to form white corpuscles; (3) to form red corpuscles. This is probably only true during the very early stages of the animal life. It may have a part in this work from its connection with the influence it has upon the red marrow. It was formerly thought that the spleen destroyed the worn-out red corpuscles. This theory has been practically abandoned; (4) that it has a special nitrogenous metabolism to perform is quite well established. The very large amount of uric acid, xanthin, and leucin favor this idea; (5) that it has an influence over the portal circulation. This function is looked upon as subordinate.

FLUIDS OF DIGESTION.

Various fluids have been mentioned, as the saliva, the mucus, the gastric juice, pancreatic juice, and intestinal juice. Where and how are these fluids made?

They are produced by the mucous membrane and by the various glands by a process called *secretion.* This is accomplished by the activity of the cells which line the glands, also by those of the mucous membrane. In this little laboratory, the cell, are made these strange compounds. The

process is a very complex one. It is not a process of sifting by which certain substances contained in the blood are taken out, for the products of secretion are very different from anything found in the blood. Again, secretion will go on in the absence of a blood supply. These are products manufactured by the cell by its peculiar and individual activity. This is normally accomplished in the following manner: —

1. An increased flow of blood is produced by the dilation of the small arteries (caused by a very beautiful arrangement of the nerves and the muscular fibers of the arteries, which will be explained when we consider blood circulation). There is a rise in the temperature of the gland, and a deepening of the color of the mucous membrane.

2. By a nervous stimulus to the cell, caused by the reflex influence of the medulla. Most of the glands, and probably all, receive the reflex nervous stimulus.

3. By the activity of the cell, which manufactures from its substance the secreting product, which it expels into the adjoining cavity. If the cells of the salivary glands be examined between the acts of active secretions, they appear very granular, hiding the nucleus, the lines between the cells being not easily made out and with a clear band at their outer margin. If, however, they should be examined at the time of the active secretion, a marked difference is noticed. The outline of the cell becomes more clearly marked, the nucleus prominent, the clear space large, and the entire cell less granular.

It would seem, then, that in those glands which are intermittent in their action, that secretion consists of two acts: (1) A passive one, in which it makes from its protoplasm the secreting product which appears as granules (or at least the secreting factors), and (2) the act by which these products are expelled from the cell into the tubules of the glands.

In those glands in which the secretion is constant, as in the liver, these acts take place simultaneously.

The saliva, the gastric juice, and the pancreatic juice are intermittent; the bile, constant.

The digestive fluids consist of a large portion of water, and an alkaline (or acid principle), and some organic ferment, the active principle in the digestion.

Mucus.— This is the fluid secreted by the general surface of the mucous membrane and by the mucous glands. It is slightly alkaline, viscid in consistency, contains a large proportion of water and a ferment called *mucin.* It has the following functions: —

1. In general, to moisten the mucous membrane.
2. By viscidity to aid in deglutition.
3. In digestion, especially in the stomach, to change cane sugar to grape sugar.

Saliva.— The saliva, as found in the mouth, is the mixture of fluids from the parotid, sublingual, submaxillary, and buccal glands. We can here speak only of the saliva as a mixed fluid. In consistency it is less viscid than mucus, contains a large proportion of water, is alkaline in reaction, its ferment being *ptyalin.* Its functions may be enumerated as follows: —

1. Generally and probably its chief function is to moisten the food, and aid in the formation of the *bolus.*
2. To dissolve substances soluble in water, and by its alkaline reaction to render many substances soluble which would not dissolve in water.
3. To aid in the articulation of speech.
4. According to Liebig, to carry down into the stomach small quantities of oxygen.
5. To change starch to maltose and other forms of sugar.
6. It is necessary to the sense of taste to dissolve sapid substances.
7. It has no digestive action upon the proteids and fats.
8. By alkaline nature, it acts as a stimulant to the gastric glands.

Gastric Juice.— As will be remembered, this is the secretion of the gastric follicles of the stomach. It has a large proportion of water, a small per cent of acid (*hydrochloric*), and a ferment called *pepsin* and *rennin.* The functions of this fluid are: —

1. To digest a class of bodies called proteids, of which we shall learn more when we study the subject of food.

2. To disintegrate the food by its solvent action on connective tissue.

3. To antisepticize the food.

4. By acid nature to act as a stimulus to the flow of the alkaline secretions of the intestine, liver, and pancreas.

The proteids of the food are insoluble, and do not readily pass through membrane by osmosis. The part of the work of the stomach digestion is to change these into the peptones, which renders them soluble. This is accomplished by the action of pepsin in the presence of an acid medium (hydrochloric).

If the gastric juice be neutralized by an alkali, the pepsin does not exercise its digestive power on proteids.

In the digestion in the small intestines there are three fluids that take a part in the action: the bile, pancreatic, and intestinal juices.

The Bile. — In composition the bile contains a large proportion of water, bile salts, and bile pigments, but no proteids or ferments.

The bile salts are sometimes called bilin, and consist of sodium glycocolate and sodium taurocolate. In the human bile the sodium gylcocolate is in excess (4.8 to 1.5). The bile also contains cholestrine (an alcohol) and a small per cent of mineral salts. The color in carnivora, omnivora, and man is a bright, golden red.

While there have been many conflicting views in regard to the function of the bile, experiments seem to establish the following uses: —

1. To aid the pancreatic juice in emulsifying fats and oils. It also has, to some degree, the power of saponification.

2. To neutralize the acid of the gastric juice.

3. To awaken the secretion of the intestinal juice.

4. To aid in the osmosis of the fats, by moistening the mucous membrane of the intestines.

5. To prevent putrefaction, by its antiseptic properties.

6. To act as an excrementitious fluid; i. e., takes from

the blood certain injurious principles, that they may be thrown from the system with the refuse of digestion.

7. To act as a stimulant to the muscular coats of the intestines.

Glycogen.— This is a carbohydrate substance found in the liver. It has a formula ($C_6H_{10}O_5$) like that of starch, and, like starch, it is converted into sugar by hydration, but it differs from starch in that it gives a wine color with iodine. The source of the glycogen is, without doubt, the food, as there is little or no glycogen in the liver of a starved animal. Its great source is the carbohydrates, as is shown by the fact that when animals are fed on diet of this kind, there is an increase of glycogen. It is also derived from proteid material. During digestion, especially after a meal rich in carbohydrates, the blood going to the liver through the portal vein contains more sugar than the blood leaving the liver by the hepatic vein. During the interval of digestion, however, the hepatic venous blood contains about twice as much as the portal venous blood. From this it would seem that the liver regulates the amount of sugar in the blood, storing it as glycogen during digestion, and reconverting this glycogen into sugar to be given to the system as its needs demand.

The destination of the glycogen of the liver is, however, to some extent, under discussion. The burden of the evidence seems to favor the view given above, that it is converted into sugar, and undergoes combustion in the tissues. Heavy muscular work leads to the disappearance of hepatic glycogen; the amount of sugar in the venous blood of an active muscle is slightly less than in arterial blood. The sugar cycle of a well-fed animal is as follows: The sugar absorbed from the alimentary canal enters the portal blood, is in great part stored as glycogen in the liver cells, is gradually reconverted into sugar, which passes by the hepatic veins, is consumed by living muscle, and discharged as carbon dioxide (CO_2) and water (H_2O).

Glycogen is also found in muscle tissue, especially in skeletal muscle, where it probably forms a local reserve for

muscular energy. By some glycogen is thought to be also a source of heat.

Pancreatic Juice.— This is a clear, viscid fluid, having a decidedly alkaline reaction with some proteids and organic ferments.

The ferments of the pancreatic juice are *trypsin, amylopsin, steapsin,* and a special *milk-curdling ferment.* Trypsin has the power of converting the proteids into peptones. It acts best in an alkaline medium, and is more powerful than pepsin in its action on both proteids and gelatins.

Amylopsin has the power of converting starch into maltose, which is converted into dextrose before absorption. Amylopsin cannot be distinguished from the ptyalin of the saliva. The milk-curdling ferment (rennet) is very powerful; one c.c. of brine extract will coagulate fifty c.c. of milk in a little over a minute.

The power of the pancreatic juice to emulsify and saponify the fats and oils is thought to be due to steapsin.

In its action pancreatic juice closely resembles the saliva, but has a much stronger action upon starch. It has the following functions: —

1. Acts with great energy upon raw or boiled starch, converting it into grape sugar.

2. Exercises an action upon proteids similar to that of gastric digestion. The following differences are to be noticed: —

a. In gastric digestion the fibrin becomes swollen and translucent, while in pancreatic it remains opaque, and seems to have suffered corrosion rather than solution.

b. The product of gastric digestion is acid albumin, while that of pancreatic is alkaline albumin.

c. The greatest difference in the production of two nitrogenous substances, leucin and tyrosin.

3. Its action upon fats is twofold.

a. It emulsifies fats.

b. It breaks up the fat into glycerin and the fatty acid, and if an alkali is present, saponification takes place.

Intestinal Juice.—This fluid is supposed to be a secretion of the crypts of Lieberkühn. Evidence is wanting as to its part in digestion; probably it has no direct action upon either fats or proteids. In some animals it has the power of changing starch into grape sugar; by fermentation action to convert cane sugar into lactic acid, and this into butyric, with the evolution of carbon-dioxide and free hydrogen.

By most physiologists its action is not considered very important.

ALIMENTATION.—EXPERIMENTS.

Prepare some arrowroot (which is almost pure starch), and make a thin paste with boiling water. Let it cool. Try the following:—

1. Add two or three drops to a test tube half full of water. Then add a few drops of a solution of caustic potash; to this add a few drops of a solution of blue vitriol (copper sulphate). Mix thoroughly, and boil for a short time over a spirit lamp.

2. After thoroughly rinsing the mouth, collect some of the saliva in a clean test tube. Dilute with water. Add the caustic potash and the vitriol as before, and boil. What change in color do you note? Is there any sugar (maltose) in the solution? How do you know there is not?

3. Take three or four drops of the paste and 10 c.c. of saliva, and mix them in a tube about half full of water. Place the tube in a warm place (about 40° C.), and let it stand for five or ten minutes. Then add the caustic potash and the vitriol solution as before. Is there any change? What does it show? What is the source of the sugar (maltose)?

4. Take a solution (the same, 3), and add a few drops of vinegar, or acetic acid, and proceed as in 3. What change do you note?

5. Take 10 c.c. of saliva in a test tube, and add two grains of raw starch. Add the same amount of starch to enough water to make a paste, and boil in a test tube, and when the paste is formed, let it cool. When cool, add 10 c.c. of saliva; set it and solution of raw starch aside under the same condition. After standing for twenty minutes, test each for maltose by adding to each 5 c.c. of Fehling's solution. In

which do you get the larger precipitate? What does this show? How do you account for the difference?

Gastric Digestion.— 1. Obtain a pig's stomach. Cut it open, and wash away its contents with a gentle stream of water. Now carefully dissect off the mucous membrane from its middle part; cut in very fine pieces, and put aside for two or three days in three or four ounces of glycerin. The glycerin will dissolve the pepsin. Now strain off the glycerin through muslin.

2. Secure from the butcher some whipped blood. Wash it thoroughly with water. Put aside in fifty-per-cent alcohol.

3. Add sixty drops, or 4 c.c., muriatic acid (*hydrochloric acid*) to a pint of water.

4. Dilute a teaspoonful of the pepsin solution of Experiment 1 with two tablespoonfuls of water. Put the mixture into a test tube, and set aside in a warm place for twenty-four hours after adding a small portion of the fibrin solution. Does any change take place? Avoid too high a heat (not over 42° C.), as the mixture should not be hot. What facts do the results show? Test for peptones.

5. Put some of the solution of Experiment 3 in a test tube, and add some of the fibrin, and put away in a warm place for twenty-four hours. What change do you notice? What does this show?

6. Fill a clean test tube half full of the mixture of Experiment 3. Add a teaspoonful of solution of Experiment 1, then add some of the fibrin. Place in a warm place for twenty-four hours. What change takes place? What does it show?

7. Proceed as in Experiment 6, but add some seventy or eighty per cent of alcohol. What effect has it upon the action of the muriatic acid and pepsin? What does it teach as to the effect of alcohol on digestion?

8. Action of Bile on Fatty Substances.— (*a*) Shake up some olive oil with water in a test tube. Do the liquids separate when you cease to shake them? (*b*) Secure some ox-gall. Now shake up some oil with the bile instead of water. What difference do you note?

9. To Make Pancreatic Solution.— Secure from the butcher the pancreas of the pig. Keep it moistened with water for a day; and after mincing well, add eight or ten times its own weight of glycerin. Set the mixture aside for

three or four days, occasionally stirring it. The glycerin will dissolve out the pancreatin. Strain through muslin.

10. To 10 c.c. of a one-per-cent solution of carbonate of soda add 1 c.c. of pancreatin. Add to this a small amount of starch paste, and set aside in a warm place where it will not be over 42° C. Examine after twenty-four hours, and test for sugar.

Take a similar solution, but add to it hydrochloric acid until the solution is acid; proceed as in Experiment 10. What change do you note? If the contents of the small intestines were acid, what effect would it have upon digestion?

11. To 5 c.c. of the solution of pancreatin add 10 c.c. of a two-per-cent solution of bicarbonate of soda. To this solution add ten or twelve drops of olive oil or a small amount of butter. Keep the mixture near 40° C. After four or five hours, what change do you note? Repeat the experiment, but omit the bicarbonate solution. Do you note any change? Examine a drop, in each case under high power. In either case is the resulting solution soluble in water?

12. Make a solution as in Experiment 7, but instead of starch take a small amount of the white of an egg. Try the experiment also with some cooked egg.

13. In a similar way try some meat.

14. Try the action of pancreatin on milk.

15. Make careful measurements of the circumferences of an egg. Soak the egg in a dilute solution of hydrochloric acid (three parts acid to one hundred parts water) until the mineral matter is removed, which may be told by the covering being soft and pliable. Make a strong solution of grape sugar (ten grams sugar to one hundred c.c. of water). Test five c.c. of the solution to determine how many cubic centimeters of the Fehling's solution it will precipitate. Place the egg in one hundred c.c. of the grape sugar solution, and leave it in the solution for several hours. Examine it from time to time to note any changes. Make a careful measurement of the circumferences of the egg after it has been in the solution. Has there been any increase in the size of the egg? How do you account for the change? Test the solution in which the egg has been soaking? Has there been any loss of the amount of sugar in the solution? Test five c.c., as above. How does the amount of Fehl-

ing's solution precipitated compare with the test first made? Carefully break the egg, and test it for grape sugar? How do you account for the presence of the sugar in the egg?

16. Prepare an egg as in Experiment 15, and, after making the same measurements, place in a strong solution of pure cane sugar (ten grams to one hundred c.c. of water). Test ten c.c. with Fehling's solution. Do you get a precipitate? Test another five c.c., first boiling with one c.c. of hydrochloric acid for a few minutes, and let cool. Add Fehling's solution. What change do you note? After the egg has been in the solution for twenty-four hours, test as in Experiment 15, but before adding the Fehling's solution, warm the solution with hydrochloric acid. What differences do you note? Does as much of the sugar pass into the egg as in Experiment 15?

17. Prepare an egg as in Experiment 15, and place in pure water for twenty-four hours. Is there any change in the size of the egg? Test the water for chlorides (see Appendix). How do you account for their presence in the water?

18. Take an egg as prepared in Experiment 15, and keep it in fifteen-per-cent salt solution for twenty-four hours. What change do you note in the size of the egg? What reasons can you give for the change?

19. Repeat the experiment, using a normal salt solution (.6 per cent). Is there any change in the size of the egg? What principles have you learned that govern the interchange of liquids (*osmosis*) when separated by a membrane?

20. Take fifteen or sixteen inches of the intestine of a rabbit; clean, wash, and inflate. Tie at intervals of four or five inches; let dry. When dry, cut midway between the tied points, thus making that into little sacks, and suspend them in convenient-sized vessels containing water. In the first, place a grape sugar solution; in the second, oil; in the third, oil with an alkali (carbonate of soda); in the fourth, milk; in the fifth, milk with a strong solution of pancreatin. Test the liquids in the respective vessels for sugar, oil, peptones. In which vessels has the substance in the sack passed through the wall of the sack into the liquid surrounding it? Which of the substances passed most readily through the membrane into the water?

DIGESTION.— TEXT.

Mastication. — This in man consists chiefly of an up-and-down movement of the lower jaw, combining the grinding action of the molar teeth with a certain amount of lateral and fore-and-aft movement.

The principal muscles (Figs. 37 and 38) concerned in these movements are the temporal masseter, internal and external pterygoids, digastric, and buccinator.

They receive their motor fibers from the fifth cranial nerve. During mastication the food is moved to and fro, and rolled about by the movement of the tongue, governed by the hypoglossal nerve. During this process there is a copious flow of saliva.

Deglutition.—When sufficiently masticated, the food is gathered up into a bolus on the middle of the upper surface of the tongue.

The front of the tongue being raised, the bolus is thrust back between the tongue and palate through the fauces. Just before its arrival there the soft palate is raised. By this and other movements the entrance to the posterior nares is blocked, while the soft palate is formed into a sloping roof, thus guiding the bolus down the pharynx. By the contraction of some of the muscles of the pharynx (*stylo and palato pharyngeus*) the funnel-shaped bag of the pharynx is brought up to meet the descending morsel very much as a glove may be drawn up to meet the finger. The thyroid cartilage is now raised by action of the laryngeal muscles, and thus it assists the epiglottis to cover the glottis.

The entrance to the nares and to the glottis being guarded, the impulse given to the bolus can have no other effect than to propel it beneath the sloping soft palate over the incline formed by the root of the tongue and epiglottis. When the bolus is large, it is received by the middle and lower constrictors of the pharynx, which, by their contraction one after the other from above downward, force it into the esophagus.

By a series of successive contractions of the circular fibers

of the muscular coats of the esophagus it is forced downward by a creeping-like movement. When the morsel is small, or when a fluid is swallowed, the movement given to it by the tongue is sufficient to force it into the esophagus without the aid of the constrictors. In the act of deglutition we may note the following stages: —

1. The thrusting of food through the isthmus of the fauces. This may be of long or short duration.

2. The passage through the upper part of the pharynx. Here the food traverses a region common both to the food and respiration, and, in consequence of this, the movement here is as rapid as possible.

3. The descent through the grasp of the constrictors. The food having passed the respiratory orifice, the passage becomes slower, with the exception of small morsels and fluids.

4. The passage along the esophagus may be considered as the last stage, but it is in reality the beginning of the *peristaltic* movements common to esophagus, stomach, and intestines.

The first stage of deglutition is voluntary. The second, taken as a whole, may be considered as reflex, although the earlier movements of this stage may be considered on the border land of voluntary and reflex action, and the third is without doubt reflex. The more recent observations warrant the conclusion that, taken as a whole, deglutition is reflex, and its center of action is the medulla.

Movements of the Stomach.—The object of the movements of the esophagus is to carry the food as rapidly as possible to the stomach,[1] and that of the intestines to carry the intestinal contents onward through the twisted course of the

[1] A careful examination of the structure as far as the muscles are concerned shows they may be divided into two portions, the cardiac portion, made of weaker muscles (the *fundus*), and the pyloric, made of stronger developed muscles (the *antrum*). The pressure produced by the muscles of the antrum is over three times as great as that of the fundus.

"The movements of the fundus serve to mix the food with gastric juice; the movements of the antrum serve to empty the contents of the stomach into the duodenum."—*Schenck and Gürber.*

looped path, and the exposure insuring the thorough mixing of its contents and exposure to the surface of the mucous membrane for absorption.

The movements of the stomach, however, have different purposes: —

1. To provide an adequate exposure of the contents of the dilated chamber to the influence of the gastric juice.

2. To propel the partially digested food, when ready, into the duodenum. We may therefore distinguish between the churning and the propulsive movements.

When the stomach is empty, all the muscular fibers fall into what may be called an obscure tonic contraction. The whole stomach is small and contracted, and its cavity nearly obliterated, and from the greater number of circular fibers, its mucous membrane is thrown into longitudinal folds. As the food enters, the muscular fibers become relaxed with the exception of the pyloric sphincter, which remains at first permanently closed, and the less marked cardiac sphincter, which merely relaxes from time to time at each act of swallowing. As soon as the coats become relaxed, they set up an obscure rhythmical peristaltic contraction, giving rise to the churning movements. These movements are feeble at first, but become more pronounced as digestion proceeds. Before digestion proceeds very far, the propulsive movements begin. These occur at intervals, at first slowly, but afterward more rapidly.

Movements of the Small Intestines.— As soon as the products from the stomach enter the small intestines, there begins a contraction of the circular muscular coats, giving an onward propulsive movement from above downward, caused by the lessening of the caliber of the intestine by the contraction of the circular fibers. Beginning at the pylorus, this movement may be traced the entire distance. The contraction of the longitudinal fibers may aid in the propulsive movement by alternating in their contraction with the circular fibers. They also aid the intestines to regain their caliber after contraction.

Movements of the Large Intestines.— They are similar in most respects to those of the small intestine, but less complicated and vigorous.

DIGESTION.— CHANGES WHICH THE FOOD UNDERGOES.

The following are some of the more important changes:—

1. The Mouth. — *a.* The food is divided, moistened, formed into a bolus, and prepared for swallowing.

b. Some of the starch is acted upon by the saliva, and changed to maltose.[1] If the starch has been cooked, a much larger proportion is changed than when uncooked. Why? (See Experiment 5.)

2. The Stomach.— *a.* The action of the saliva upon the starch is arrested.

b. The gross effect is to break up and partly dissolve the larger lumps of masticated food into a thick, grayish soup-like *chyme,* with which are still mixed variable quantities of larger and smaller masses of less changed food.

In meat, by the solution of the connective tissue binding them together, the muscular fibers fall apart, and they are ultimately reduced partly to granular mass and partly to actual solution.

The fats have the connective tissue binding the cell together and the envelopes of the fat cells dissolved and the fat set free.

In vegetable substances the proteid elements are in part dissolved, and although there is no evidence that in man the cellulose is dissolved in the stomach, the whole tissue is softened, and to a certain extent disintegrated.

The chyme in general as it passes into the duodenum consists of: —

[1] The common statement that starch is converted into grape sugar (glucose) by the action of saliva and pancreatic juice is not true. While the substance resulting from this action reduces Fehling's solution, it is quite different in its composition, and is called maltose, or malt sugar. The change which takes place in the digestion of starch is not a simple one, as commonly described, but is very complex, in fact, too complex to be described here. It should be stated, however, that there is a small amount of glucose formed by it that results from a secondary action, and not from the action of the ptyalin on the starch. It is formed from the maltose.

1. Starch unchanged by the saliva.
2. Oils and fats set free in the gastric digestion.
3. Dissolved proteids.
4. Undissolved proteids.
5. Debris of indigestible materials, as cellulose, etc.

Recent experiments seem to show that the amount of material actually dissolved in most specimens of chyme is very small. It is further shown that the action in the stomach is more one of preparation to digestion than of completed digestion; i. e., *the great purpose*[1] *of gastric digestion is to reduce by disintegration the lumps of food to a more uniform mass, and thus facilitate the changes which are to take place in the small intestines.* During the process, however, some of the material is converted into peptone, and the peptone thus formed is in part absorbed at once, but the greater part of the proteids remains unchanged, at least they are not converted into peptone. There is little or no change produced upon starches and fats.

Sudden mental excitement may delay gastric digestion; also feeble and imperfect digestion may arise from purely nervous influences. An excessive formation of acid may be due to nervous disturbances. Anger and surprise often destroy the appetite and arrest digestion.

3. In the Small Intestine.— The semi-digested acid food from the stomach as it passes over the biliary duct causes a flow of bile and pancreatic juices which tend to neutralize the acid chyme, but the contents of the duodenum do not become distinctly alkaline until they have proceeded some distance beyond the pylorus.

By intestinal digestion the following results are secured: —

1. The change of starch into sugar is resumed.
2. Proteids are largely dissolved, probably by action of

[1] Stomach digestion has another very important function, that of thoroughly disinfecting the food. This is accomplished by the free hydrochloric acid, and also by the acid compounds it forms in digestion. This explains why a person may drink infected water during the digestion of a meal, which, if taken between meals, might prove fatal.

the bile and pancreatic juice, and to some extent possibly by the intestinal juices, assisted by various micro-organisms.

3. Starch converted into sugar, and possibly the sugar is in part converted into lactic and other acids.

4. Fats are largely emulsified and to some extent saponified.

5. By the time the food has reached the ileocæcal valve it has been deprived of most of its nutritious properties, but by no means all.

6. Such is the relation of water secreted in the intestine to that of the fluids absorbed, that the intestinal contents at the end of the ileum are about as fluid as in the duodenum.

4. In the Large Intestine.— Among the more important changes the following may be noticed: —

1. The contents become distinctly acid. That is not due, however, to the secretion of the intestinal walls, but to the acid fermentation which takes place in the contents of the intestines.

2. Of the changes which take place we have no definite knowledge. It is probable that digestion of cellulose takes place here.

3. Absorption is very active, and the contents soon lose their fluid consistency.

Absorption.— The digested food must pass from the alimentary canal into the blood so that it may get to the tissues. The process by which it is accomplished is called absorption. The great absorbent vessels are the veins and lacteals, but in the process of absorption the veins perform the greater part.

All along the course of the alimentary canal the mucous membrane is closely packed with blood vessels and lymphatics, so that as soon as any soluble substances are formed, they may be absorbed. The time of the passage of the food from the mouth to the stomach is so short that little absorption takes place before the food reaches the stomach. But while absorption takes place actively in the stomach, the intestines are the part most concerned in this process.

It will be remembered that the villi are minute tubules projecting into the intestinal contents like the minute rootlets of the plants into the soil; that it is covered with a layer of cells resting on a fine reticulum; that it contains a network of capillaries and lacteal axes and lymph spaces (Figs. 117 and 118). In order, then, for the food to enter the blood or the lymph it must pass through the cells and reticulum of the villus and the cell layer of the capillaries. In absorption we may, therefore, distinguish two stages:—

1. The passage through the epithelial cell of the walls of the villus and through the reticulum.

2. The passage through the epithelial cell of the capillaries or the lymphatic radical.

Experiments indicate that the first stage is something more than diffusion, or osmosis. It is accomplished by the activity of the epithelial cells, and it is, in one sense of the term, a vital process; for in case of fats, repeated observations have shown that the neutral fats enter the cell substance, and also that peptones are changed in their passage through the cell substance.

The passage of the food materials through the walls of the villus is something more than osmosis; it is a process in which the activity of the cell plays an essential part. The passage through the cell walls of the capillary is more of the nature of osmosis, but that the tissues are living must not be lost sight of.

The greater part of the peptone is absorbed by the veins, while the fats are almost entirely absorbed by the lacteals. The contraction of the villus and the presence of valves in the lacteals aid in the passage of the fats through them.

When we study circulation, we shall then trace the course food takes after it is absorbed.

How the Food Gets to the Tissue.— By the act of absorption the food material enters two streams, (1) the blood, and (2) the lymph.

By the absorption of the food in the stomach the digested proteids, soluble substances, and water leave the stomach

and enter the blood by the gastric vein (Fig. 124; see also Fig. 127); the digested proteids, starch (sugar) for the greater part, leave the intestine by the mesenteric veins; these veins and the gastric vein pour their contents into the portal vein; the portal vein carries the food to the liver; the portal vein breaks up into capillaries through which the materials pass, and are collected into the hepatic veins which carry them to the ascending vena cava, by which they pass to the right auricle of the heart.

The greater part of the digested fats with probably some of the digested proteids and starch are absorbed by the lacteals of the intestine; from these the absorbed materials pass through the mesenteric glands, and from these to the receptacle of the chyle (*receptaculum chyli*), the beginning of the thoracic duct; by the thoracic duct are carried along the posterior part of the thoracic cavity, and after making a small arch, empties into the left subclavian vein near its union with the internal jugular vein; then into the left innominate vein from which it passes into the descending vena cava; then into the right auricle of the heart.

Notice that the materials absorbed by the lacteals have reached the same destination as those absorbed by the veins, but by a very different route.

From the right auricle the material passes to the right ventricle, by the pulmonary artery to the lungs and after passing through the terminal capillaries is collected into the pulmonary veins and brought to the left auricle from which it passes to the left ventricle, and then into the aorta by whose branches it reaches the tissues of the various organs of the body. Carefully study diagram, Fig. 127.

THE ACTION OF ALCOHOL ON DIGESTION AND THE DIGESTIVE ORGANS.

The action of alcohol on any organ may be traced to one or to all of the following sources: (1) Its action on the blood vessels, causing the enlargement or dilation of the vessels, thus increasing the blood supply to the organ; (2) stimulating through the nerve a more vigorous action; (3) the direct

effect on the cells of the tissue interfering with its normal metabolism.

When taken in moderate doses, it causes a slight reddening of the mucous membrane, the degree of redness varying with the size and frequency of the dose.

If alcoholic drinks be taken habitually, they will destroy the tonic condition of the blood vessels and produce in them a chronic congestion, more or less pronounced, as the habits of the individual are moderate or immoderate; and in extreme cases, they may bring about an ulcerated condition.

When alcoholic drinks are not used habitually, but only occasionally, if blood vessels become dilated and congested, it is only temporary. They will return to their normal condition on ceasing the use of the alcohol.

The first effect of alcohol on the process of digestion is to precipitate the pepsin of the gastric juice. But by the stimulating effect of the alcohol there is brought about an increased action of secretion, and the final result of a moderate dose of wine, brandy, or similar drinks is to aid digestion.

It might be asked, then, if this is true, would not the constant use of alcohol be a good thing? — *Emphatically no.* Its habitual use brings about exhaustion of the glands by overwork, a chronic congestion of the blood vessels, which conditions result in some of the worst forms of dyspepsia. There is great danger that its everyday use will create a love for alcoholic drink, a thing greatly to be feared. The physician should be very careful how he prescribes its constant use.

It is to be doubted whether it interferes with digestion by coagulating the proteids of our food as stated in some works on physiology. It is true that eighty or ninety per cent alcohol will harden the white of an egg, but it should be remembered that alcohol is not taken this strong; seldom over sixty per cent, and this diluted by two or three times its volume, so that when mixed with the food in digestion, it is diluted to a low per cent. A twenty or thirty per cent alcohol hardens a tissue very slowly. Try the experiment.

Even in artificial digestion of fluids, if the alcohol does not form over eight or ten per cent of the liquid, it will not precipitate the pepsin nor interfere with the digestion.

CHAPTER VIII.

FOOD.

EXPERIMENTS AND DEMONSTRATIONS.

1. Weigh a small potato, and put in a drying oven (air bath) and keep at a temperature of 100° or 150° C. until thoroughly dried. If you have no drying oven, dry in the cook stove. Weigh the potato again. Determine the loss of weight due to drying. To what is the loss of weight due? Dry a potato on a glass under a bell-jar, in the sun or on the radiator. What is the source of the moisture that collects on the side of the bell-jar? A large glass fruit can may be used in place of the bell-jar.

2. Determine by Experiment 1 the proportion of water in the following: a ripe apple, lean meat, fat meat, cabbage, carrots, dried beef, and a fresh biscuit. Make a table of the per cent of water in the foods tested.

3. Take the potato dried in experiment, and burn it in a porcelain crucible or in an iron sand bath. Weigh the ashes. What proportion of the potato is ashes? The ashes represent the amount of mineral matter in the potato. Test the ashes for the following: potassium, sodium, calcium, phosphates, and carbonates. (For tests see Appendix.)

4. Determine the ash (mineral matter) in the following: lean meat, corn, wheat, beans, and egg. Test the ashes of each as in Experiment 3. Which seems to have the most phosphates? the most potassium?

5. Thoroughly mince one or two ounces of suet or fat meat, and soak in three or four fluid ounces of benzine for forty-eight hours. Pour off the liquid, and set the liquid aside to let the benzine evaporate. (Keep the benzine away from the flame.) What is the nature of the liquid you have left? Weigh the liquid. How does the last weight compare with the first weight?

6. What per cent of butter is fat or oil? Test by dissolving one-half ounce of butter in four or five times its volume of benzine. Does it all dissolve? Pour off the

liquid into an evaporation dish or saucer, and set aside to let the benzine evaporate. Save the part that did not dissolve, as you will need it in Experiment 14. What per cent of the butter is fat?

7. Determine if the following contain oil: corn, wheat, oatmeal, Brazil nuts, walnuts, lard.

8. Make some starch paste. Add to a small portion in an evaporation dish a few drops of a solution of potassium iodide (see Appendix), and then add a few drops of chlorine water; the solution will turn purple or nearly black.

9. Test the following for starch: corn, wheat, rice, oatmeal, tapioca, and beans. Grind each to a fine powder; make a paste, and test as in Experiment 8.

10. Remove the peeling, and test some of the scrapings from the flesh of the following, for starch: potato, turnip, apple, and carrot.

11. Place a drop of the liquid obtained from scrapings of the potato on a clean glass slip, put on cover glass, and examine with two-thirds and one-sixth objective. Make drawing. Examine in same drop of the liquids from the other objects taken in Experiment 10.

Put a small amount of cornstarch on a slide, and add a drop of water. Examine with two-thirds and one-sixth objectives. Compare the size and form of the starch grains obtained in each case.

12. Examine under high power a very thin slice of potato. Avoid two great pressure on the piece. Where are starch grains found?

13. *a.* To the white of an egg in a six-inch test tube add three or four times its volume of water. Stir thoroughly, and place about one c.c. in a four-inch test tube, and boil. The heat causes the hardening (*coagulation*) of the albumin.

b. To a fresh portion in a clean test tube add, drop by drop, ninety-five-per-cent alcohol until the albumin is coagulated. Try another portion with ten-per-cent alcohol. What difference do you note in the result?

c. Heat another portion with nitric acid in a six-inch test tube, and note change of color to yellow. When cooled, add a few drops of ammonia water (*ammonium hydroxide*) which deepens the color (*xantho-proteic reaction*).

d. To another portion add a small amount of a solution

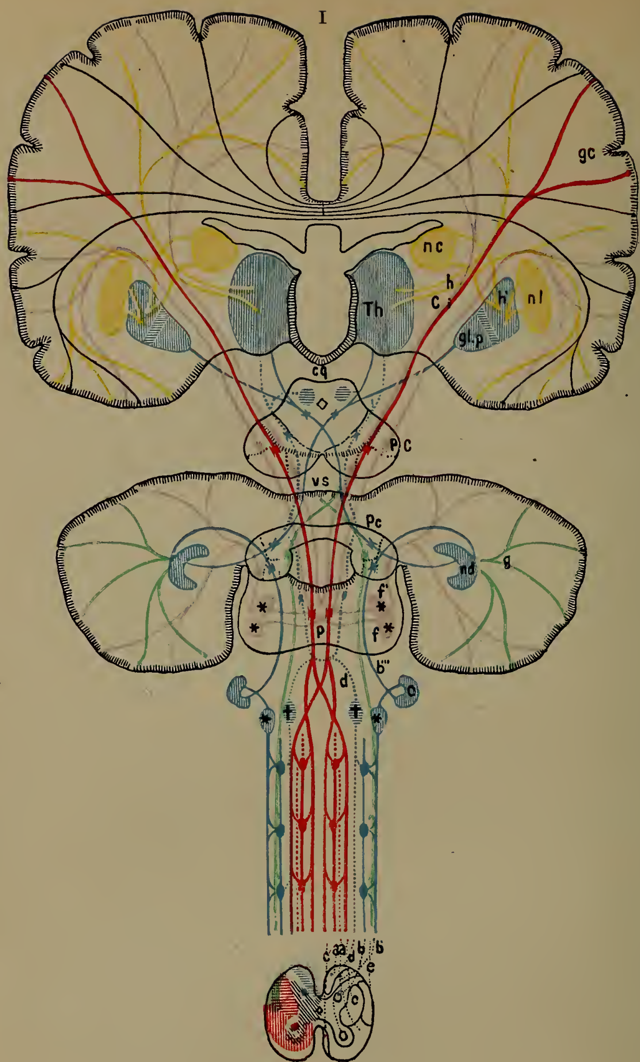


PLATE IX.

FIGS. 72 and 73.—A DIAGRAM OF THE COURSE OF THE NERVE FIBERS IN THE SUBSTANCE OF THE BRAIN AND SPINAL CORD.

(Study in connection with Plate X.) (After Aeby.) (From Ranney.)

I. View of a transverse section. II. Profile view. III. The nuclei of the medulla (partly after Erb). The crosses of color corresponding to the lines upon which they are placed, designate the point of section of each tract as it passes through different levels (the crus and pons.) C i. Internal capsule, with radiating fibers (in yellow), pyramidal fibers (red), and fibers going to the pons (in purple). P C. The crura cerebri, with the pyramidal fibers and the fibers going to the ganglia of the pons anteriorly, and posteriorly, the substantia nigra, the fillet tract (in dotted lines), the fibers of the superior peduncle of the cerebellum (in blue). Pc. The peduncles of the cerebellum, showing the fibers going to the cerebrum, the pons, and the medulla. P. Pons Varolii, with its ganglia on either side (in purple).

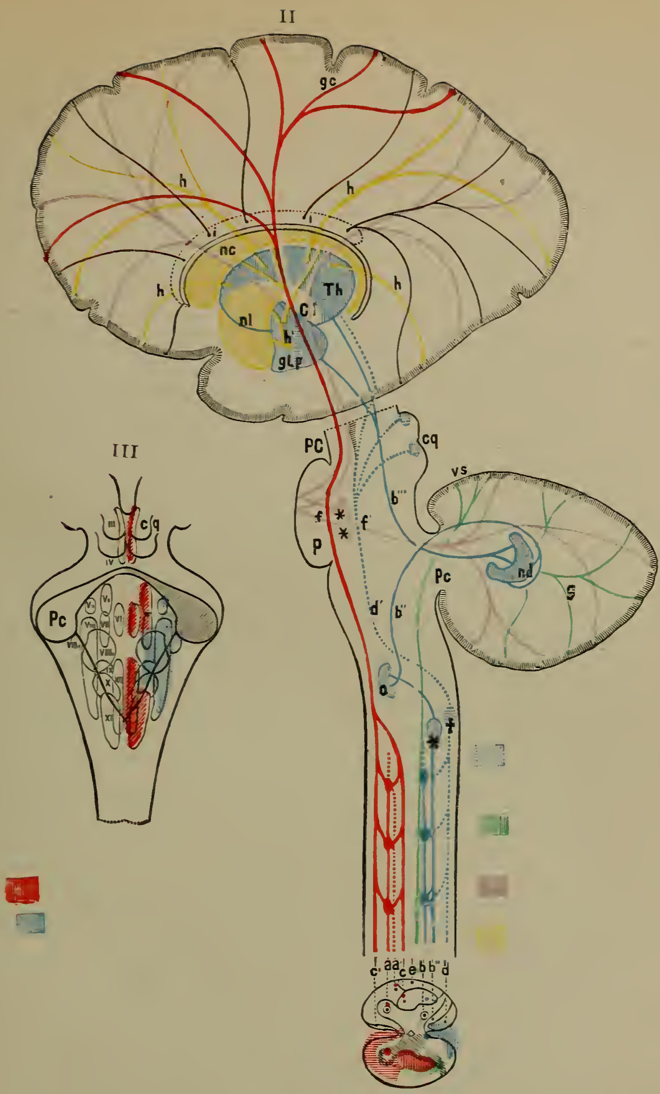


PLATE X.

Fig. 73. (From Ranney.)

In III, the nuclei of the cranial nerve roots are numbered to correspond with the nerves. Red is used for the motor nuclei, and blue for the sensory nuclei. The tracts in the cord are designated by the area similarly colored in the cross-section of the cord beneath. c'. Column of Türck. c. Crossed pyramidal column. a. Anterior horn. a'. Anterior root zone. e. Direct cerebellar column. b. Posterior horn. b'. column of Burdach. d. Column of Goll. Higher up are seen, b". The inferior peduncle of the cerebellum. d'. The fillet or lemniscus tract. f. the fibers connecting the ganglia of the pons with the cerebrum and cerebellum. b'". The fibers of the superior cerebellar peduncle. h. The caudo-lenticular and thalmo-cortical fibers. i. The commissural fibers (see Fig. 6). Th. Optic thalamus. nc. Nucleus caudatus. nl. nucleus lenticularis. gc. Central convolutions.

[In this diagram, the course of b" seems to be in error in not undergoing a decussation.—AUTHOR.]

of blue vitrol (*copper sulphate*) and an excess of caustic soda (*sodium hydroxide*). The solution changes to a purple (*Biuret or Piotrowski's reaction*).

e. Add to another portion a few drops of Millon's reagent (see Appendix); a white precipitate is produced. Boil, and note the change to pink.

f. Test another portion with a solution of ammonium sulphate solution, which will precipitate the albumin when saturated with the solution.

g. To one hundred c.c. of the solution of albumin add an excess of acetic acid and a saturated solution of Glauber's salts (*sodium sulphate*), which will give, on boiling, a white precipitate.

The seven tests given above are the ones usually used for a class of substances called *proteids*.

14. Test the following for proteids: lean meat, the pulp of fruits, cheese, beans, Graham flour, milk, butter, and bread. In case of milk, precipitate the casein with acetic acid, and filter. Dissolve some of the casein in lime water. See how many of the tests given in Experiment 13 apply to casein. Boil some milk, and apply test *a*. What reason can you give for the coagulation of milk on souring?

For the meat, put a small portion in cold water in a flask, keeping it at about 30° C. for an hour, and then boil until the meat is cooked. Test the solution obtained for proteids. Is there much of the meat that does not dissolve? Test both cold and boiled solution of each of the other objects. What difference do you note?

15. Dissolve one or two small pieces of white stick candy in a test tube. To a small portion of the solution in a four-inch test tube, add fifteen or twenty drops of Fehling's solution (see Appendix), and boil. A red precipitate (*cuprous oxide*) is formed, due to the reducing power of the grape sugar.

16. Test with Fehling's solution a solution of the following: crushed grapes, syrup, honey, solution from germinating grains (wheat or rye), dates, maple sugar. In which do you find grape sugar (*dextrose*)?

17. To ten c.c. of a strong solution of cane sugar, common granulated sugar (*saccharose*), add to the fifteen c.c. of Fehling's solution, and boil. Does cane sugar reduce the Fehling's solution? How can you tell cane sugar from grape sugar?

18. To twenty c.c. of a strong solution of cane sugar add two c.c. of strong muriatic acid (hydrochloric acid), and boil for an hour or more; let cool.

Test five c.c. of the solution with ten c.c. of Fehling's solution. Is the copper reduced? The acid changes the cane sugar to glucose. Repeat the experiment, using dilute sulphuric acid in place of the hydrochloric.

19. Test a solution of milk sugar the same as in Experiment 17.

20. Treat a half gram of starch with twenty or thirty c.c. of hydrochloric acid, and boil. After cooling, add fifteen or twenty c.c. of Fehling's solution. Into what has part of the starch been changed? Repeat the experiment, using sulphuric acid in place of hydrochloric. Do you get the same result?

21. *a.* Make a thick syrup of granulated sugar. To five or six c.c. of the syrup in a six-inch test tube add drop by drop strong sulphuric acid until the syrup turns black and becomes jelly-like. The black substance is the carbon of the sugar, the other parts of the sugar (hydrogen and oxygen) having been removed by the acid.

b. Heat on a sand bath in an evaporation dish one or two grams of sugar until it is reduced to a black mass. What is this black substance?

c. Heat a gram of granulated sugar in a six-inch test tube; carefully watch for any moisture that may collect on the cooler parts of the tube. Heat until the sugar is reduced to a black mass. What is the source of the moisture that collects on the sides of the tube?

d. Show that meat contains carbon.

FOOD.— TEXT.

Need of Food.— From a physical standpoint, our bodies may be considered as a machine, whose purpose it is to produce motion, generate heat, and maintain life.

It is the most wonderful of machines; it not only has the power of maintaining its activities, but also the power of growing stronger and larger by its own activities.

Would it not be a wonderful engine that could, from the material put in its furnace, make its own wheels, rods, boilers, furnace, and other parts, and after years of use should

be larger, stronger, and more efficient in its work? Such a machine is the human body, and in the adaptation and perfection of its parts, the possibilities of its movements, the most wonderful of machines.

No machine can originate energy or do work of itself. The unwinding of the spring moves the works of the watch, but the spring is first wound so it will be on a tension. The engine of itself cannot pull the loaded train; it can only do so when water is placed in its boiler and fuel in its furnace, so that heat set free by the burning of the coal causes the expansion of the steam, and the steam transfers its energy to the piston rods, and these in turn to the wheels. The energy here comes from the stored-up (potential) energy of the coal, set free in the form of heat (kinetic energy) by the burning of the coal.

What fuel and water are to the engine, bread, meat, and many other foods are to the body. The bread and meat contain stored-up energy (potential), which may be set free by the cells of the body in the form of heat, nerve force, and muscular force.

Our food must be more than an energy producer; it must, in addition, furnish materials to repair the waste, and as the body is a self-constructing machine (in that it must grow), it must also furnish material for increasing the size of the organs.

There are some of our foods which do not furnish energy to the body nor build up its active tissues. To this class belong those (1) which give consistency to tissue, as the water in the blood and the chondrin in cartilage; (2) that furnish a medium of exchange between the tissues, as the water in the blood and lymph; (3) that furnish the proper condition for the chemical changes, as the alkalinity of the bile and pancreatic juice, and the presence of soluble lime salts in the blood in relation to the coagulation of the blood.

Foods [1] may be defined as those substances which may be

[1] A clear distinction should be made between a food, a medicine, and a poison. A food, as we have seen above, is a substance which is of use to the body in

appropriated by the tissues of the body, and be of use to it in the production of energy, building up tissue, or in aiding in or effecting any of its physical and chemical processes.

Mineral Foods.— Of the mineral foods, water is the most abundant in the tissues of the body, making up sixty-five per cent of its weight in the adult, and over seventy per cent in the infant. The following table gives the amount of water in most of the organs of the body: —

PERCENTAGE OF WATER AND ASH IN THE BODY.

ASH.

Skeleton	22.0	Heart	1.1
Muscles	1.5	Pancreas	1.0
Liver	1.3	Brain and spinal cord	1.0
Spleen	1.2	Blood	0.9
Lungs	1.1	Kidneys	0.8
Intestines	1.1	Skin	0.7

WATER.

Adipose tissue	15.0	Pancreas	78.0
Bones	50.0	Blood	79.0
Liver	70.0	Lungs	79.0
Skin	70.0	Heart	79.0
Spleen	77.0	Kidney	83.0
Muscles	77.0	Lymph (Kirk)	90.0
Brain and spinal cord	78.0	Vitreous humor	98.7
Intestines	78.0	Cerebrospinal fluid	99.0

Schenck and Gürber: Henry Holt & Co.

Water is found in the flesh of animals, in eggs, fleshy fruits, and in various liquid foods, as coffee, tea, cocoa, etc. As our foods do not generally contain enough water for the needs of the body, it has to be taken alone. Water serves the following uses: (1) To give consistency to tissue, as in the blood and muscles; (2) as a solvent, and as such making possible chemical and physical processes, as osmosis, filtration, circulation, and chemical action of dissolved substances; (3) as a regulator of heat by its evaporation from the surface of the body and the lungs; (4) takes part in chemical changes.

Other Minerals.— When the body is burned, these make

keeping up its normal process; a medicine is a substance which tends to restore the normal processes when they have become deranged by disease; a poison is a substance which *deranges* the *normal condition* of the *body*.

Which of these actions the substance performs depends upon the amount taken and the conditions under which it is taken.

up the ashes. While they do not form a large part of the weight of the body, they serve a very important purpose.

The Phosphates.— These are the most abundant of the salts of the body, being eighty per cent of their weight. They are derived from the tissues of animals and plants, and are especially abundant in grains of wheat, oats, and corn, and in animals in the muscles. Their importance in the body is: (1) As an important constituent of the cell, being essential to regeneration of the cell substance (*potassium phosphate*); (2) as a constituent of bone, and making up the greater part of the mineral of the bone (*calcium and magnesium phosphate*); (3) to aid in the coagulation of the blood.

The Chlorides.— Next in abundance of the salts of the body is common salt (*sodium chloride*). It is found chiefly in the fluids of the body, and but little in the cells. It is not found in sufficient amount in our food, so that it is added to many of our foods, not only to heighten their flavor, but also to supply the demands of the body for this substance. Its more important uses are: (1) To aid in the solution of certain substances, as globulin; (2) to regulate the course and equilibrium of the flow of the liquid of the tissues [1] (*osmotic pressure*); i. e., it prevents the entering of water into the cells; (3) as material for the gastric gland, from which to make hydrochloric acid; (4) to stimulate muscular action.

Potassium chloride is more abundant in the cell substance than the sodium salt, but found but little in the fluids of the body. It is found in sufficient quantities in our food for the needs of the body.

Carbonates.— The more important of these is *calcium carbonate*. The carbonates serve the following uses: (1) As

---

[1] From what has been said, it will be seen why we add normal salt solution to fresh tissue when teasing them, rather than water. When tissues are placed in water, the cells become swollen, and the true structure of the tissue destroyed. If the tissue be placed in a solution containing more salt, then the tissue becomes shrunken by giving up its water to dilute the salt of the liquid in which it is placed, resulting also in the breaking down of the tissue.

The normal salt solution is of the same degree of saltness as the liquid of the tissue, hence there is neither an inflow nor an outflow, and the proper consistency of the tissue is secured.

a part of the mineral of bone and the chief mineral of the granules (*otoliths*) of the inner ear (*calcium carbonate*); (2) to aid in the excretion of carbon dioxide (*calcium bicarbonate* and *sodium bicarbonate*); (3) to aid in the alkalinity of the tissue fluids (*sodium carbonate*).

Salts of Iron.— These are important in the formation of the pigments of the blood. With the exception of common salt, all the above-named salts are contained in sufficient quantities in our food.

ORGANIC FOOD.

The organic foods may be divided into three classes: Carbohydrates, fats, and proteids.

Carbohydrates.[1]— These include the sugars, starches, gums, and cellulose of our food, and are generally divided into, (1) the simple sugars (*monosaccharides*), including grape sugar and fruit sugar. They are found in fruits, in beets, onions, and in honey; (2) the double sugars (*disaccharides*), which include cane sugar, milk sugar, and maltose. All of these are important foods. Cane sugar is found in sugar cane, sorghum, sugar maple, beets, coffee, in many nuts, as walnuts, hazel nuts, almonds, and in honey. Sugar of milk (*lactose*) is found in the milk of various animals. Maltose is found in germinating grains, and in many malted liquors, in which it is formed by the action of the malt on the starch of the grains; (3) the complex sugars (*polysaccharides*), which include starch, glycogen, dextrin, gums, and cellulose.

Starch is found in most grains, in potatoes, and in green fruits. Starch is insoluble in water or the fluids of the body,

---

[1] These were so named from their containing hydrogen and oxygen in the same proportion as found in water. We now know carbohydrates which do not have the hydrogen and oxygen in the proportion found in water. There are some compounds which have the hydrogen and the oxygen in the proportion found in water, which are not carbohydrates. The term, while it cannot be used in its original sense, has become so well fixed that it is not best to change it. When we first began to study these compounds, they were considered as simple ones, but we now know them to be very complex. The physiological importance of carbohydrates to the body is in the formation of glycogen and fat. The carbohydrates furnish material for combustion, which furnishes the body with energy for heat and for work.

and would have no food value, but as it can be converted into sugar by the ferment (*ptyalin*) of the saliva and by the ferment (*amylopsin*) of the pancreatic juice, it is a very important food.

Glycogen, sometimes called animal starch, is found in the liver and in the muscles. It is not so valuable for its food qualities as it is important as the form in which the carbohydrates are stored up in an insoluble form and held in reserve until needed by the tissues. Glycogen is to the animal body what starch is to the plant.

Cellulose, found in various parts of the higher plants, is of little food value, as it is almost indigestible, but it is of interest in its relation to starch, as it makes the covering of the grains, and must be broken before the starch can be digested. It is, however, of great value to many animals, as sheep and cattle, as it is one of the chief constituents of the grasses.

Fats and Oils.— These are found in the seeds and fruits of some plants, in milk, and in the tissues of animals. As they occur in our food, they are a mixture of two or more fats in varying proportions.

The three more important fats are stearin, the chief constituent of tallow; palmitin, the principal part of human fat; and olein, the chief ingredient of most oils. Butter is a mixture of a number of fats.

The oxidization of fats is one of the chief sources of heat to the body. They serve also other important uses, which have been mentioned.

Proteids.— These are very complex[1] substances, composed of carbon, 50 to 55 per cent; hydrogen, 6.5 to 7.3 per cent; nitrogen, 15 to 17 per cent; oxygen, 19 to 24 per cent; and sulphur, 0.3 to 2.4 per cent.

[1] We know very little of the constitution, molecular weight, and formulæ of proteid compounds. We know, however, that their molecular weight is very large and their structure very complex.

"The crystallized serum albumin of the horse is supposed to have a molecular weight of 17,070, and the empirical formula of C_{755} H_{1215} N_{195} S_{10} O_{235}."—*Schenck and Gürber.* Compare the molecular weight and the formula just given with that of common salt, which has a molecular weight of 58.5 and the formula NaCl.

There is also present a small amount of phosphorus, iron, magnesium, calcium, potassium, and sodium. While these compounds in many cases bear a close relation to the proteid molecule, yet they are by most physiological chemists not considered as essential to its structure. While they form no part of the proteid molecule, they are very important in relation to the work of the protoplasm.

For the classes of proteids, see the diagram of the classification of foods. As we shall use the term "proteid," the term includes the albuminoids, which differ chemically, physically, and physiologically from true proteids.

The more important proteids are albumin, casein, myosin, gluten, and legumin.

Flesh of Animals.— The more important are the flesh of the ox, which furnishes beef; sheep (mutton and lamb); pig, giving us pork, bacon, and ham; and of domestic fowls. Of these, beef is the richest in nutritious matters, firmer, and more satisfying and strengthening, although mutton is considered the more digestible. While the flesh of young animals is more tender, it is more indigestible. Pork is quite indigestible, and contains a smaller amount of proteids, but a larger proportion of fat. Fish and oysters are rich in proteids, but poor in salts and fats.

Flesh contains: (1) Proteids — myosin, globulins, serum albumin, gelatin, and elastin (from the connective tissue); (2) extractive, which gives flavor, as creatin, also sarcolactic acid, taurin, xanthin, and others; (3) mineral salts, the chief of which are those of sodium potassium, calcium, and magnesium, as phosphates, carbonates, or chlorides; (4) water, from fifteen to seventy-two per cent; (5) fats, from three to thirty-one per cent, including the common fats, as well as some of the more complex ones (*lecthin* and *cholesterin*), the latter, however, is not a fat, but an alcohol, but with the fat acids forms fats); (6) carbohydrates, as dextrin, grape sugar, and, in the flesh of young animals, glycogen. For the composition of the more important meats, see page 321.

Milk.— For young animals, milk contains all the elements

of a typical food. Its principal constituents are: (1) Proteid substances, as caseinogen and serum albumin; (2) fats, various fats, principally in the cream; (3) carbohydrate, milk sugar (*lactose*); (4) salts, the chief of which is calcium phosphate; (5) water, a large percentage.

The oil in milk is incased in a covering, consisting of caseinogen and serum albumins. By the process of churning, the oil globules are deprived of their covering, and the collected fats make up the butter, the proteid coverings being left in the buttermilk, and hence this liquid is rich in proteids. Cheese is principally casein, formed by the coagulation of the caseinogen by the rennet ferments. The proportion of fats it contains depends largely upon the method of its manufacture. While rich in proteids, it is difficult of digestion.

Eggs.—These, like milk, contain the elements of a typical diet. They contain proteids in the form of *egg-albumin* and *globulins,* the most important of which is vitellin, found in the yolk, and *nuclein,* found in connection with iron. They also contain, in addition to the three common fats, yellow fat, lecithin (a very complex fat), cholesterin (an alcohol), and organic salts, of which the potassium chloride and phosphates are the more important.

Vegetables.— The vegetables richest in proteids are the fruits of the plants of the pulse family, represented in our food by peas, beans, and lentils, which contain a proteid substance called legumin (sometimes called vegetable albumin), of which they contain 25.3 per cent.

The grains of wheat, oats, and barley contain proteids in the form of gluten, which is a very valuable food material, and one of the important elements of bread.

The pulps of ripe fruits, onions, and potatoes contain proteids.

Albuminoids.— These are derivatives of the proteids, and are represented in our foods by *elastin,* from elastic tissues; *callagen,* from connective tissue and cartilage, which, on boiling in water, yield *gelatin.* The albuminoids have little food value, as they cannot replace "the used-up body pro-

teids as the other proteids do." As a rule, they are difficult of digestion.

While they do not go to make up the cell substance, they are of importance in that they go to make up material for the skeletal parts of the body, as connective tissue, tendons, ligaments, cartilage, and bone.

The Qualities of a Good Food.— A good food should possess the following qualities: —

1. It should contain the principles (*proximate principles*) contained in the tissues of the body, and in as near the same proportion as possible.

2. It should be digestible. Chemically, a substance may contain the elements needed by the body, but if they cannot be digested, it cannot be taken up by the blood, and by it distributed to the tissues.

3. It must be palatable. An agreeable taste is one of the essentials to a good secretion of the saliva. Good insalivation is an important part in securing good digestion.

4. It must not be too concentrated. A certain amount of water and débris is essential to a good food. A diet consisting entirely of extract of meat, starch, and oils would be in the highest degree unwholesome. This is why fruits and vegetables should be added to our meat and bread. They give to the food bulk, and while they contain material that is indigestible, these indigestible materials serve a very important part in exciting the peristaltic movements of the alimentary tract. Persons suffering from constipation should avoid concentrated food, eat Graham bread, fruits, vegetables, and drink freely of water.

5. It should not be too dilute. The dilute food begets an undue enlargement of the stomach and intestines, as large quantities are required to give the body the proper amount of nutrient material. This excess of liquid tends to overwork the absorbent and excretory organs and produce corpulency. Hence beer as an article of diet is objectionable, and the truth of what has been said is well illustrated by those who use it freely, either as a drink or food.

It should be remembered that there is a great difference in individuality, and the degree and concentration of our food must vary within certain limits, one person requiring a somewhat concentrated food, another requiring a more or less diluted food. We should, therefore, carefully watch the effect upon us of our diet, and choose the one that serves us best.

Reasons for Cooking Food.— Much of our food is unfit for digestion in a raw condition. The more important reasons for cooking food are: —

1. To soften and disintegrate the substances, as meats and many vegetables.

2. To develop the flavor and render the food more palatable, as the baking of bread and meats.

3. To protect the system from injurious germs that may infest our food, as bacteria in fruits, milk, and water, and parasites in dried fruits, meats, and cheese. Pork should never be eaten raw, as there is danger from *trichina,* but should be cooked with especial thoroughness.

4. To bring the food more nearly to the temperature of the digestive organs. When lower than that of the digestive organs, it retards digestion by lowering the temperature, and tends to congest or chill the mucous membrane. The thirst experienced by drinking ice water is produced by the irritating effect caused by the congestion it produces. Iced tea and similar beverages should be used with great care.

Condiments. — Spices and other condiments should be used with care. The danger is not in their proper use, but in their abuse. Properly used, they are of importance (1) in rendering the food more palatable; (2) in acting as antiseptics, preserving the food; and (3) as stimulants to the muscular coats of the stomach and intestines (as *carminatives*), and also to increase the flow of the gastric juice (probably more by reflex influence, by their action in the mouth, than by their direct effect on the stomach). A free use of them produces indigestion by overstimulation, and creates a morbid appetite.

CLASSIFICATION OF FOOD

A. Mineral — Not Producing Energy
- I. *Water.*
- II. *Salts.*
  - 1. Carbonates.
    - *a.* Calcium.
    - *b.* Potassium.
    - *c.* Sodium.
    - *d.* Magnesium.
  - 2. Phosphates.
    - *a.* Calcium.
    - *b.* Magnesium.
    - *c.* Potassium.
  - 3. Chloride.
    - *a.* Sodium.
    - *b.* Potassium.
  - 4. Salts of Iron.

B. Organic — Energy Producing.
- I. *Proteids.*
  - 1. Simple Proteids.
    - *a.* Albumins.
      - (1) Serum Albumin.
      - (2) Egg Albumin.
      - (3) Lacto-albumin.
      - (4) Muscle Albumin.
    - *b.* Globulins.
      - (1) Serum Globulin.
      - (2) Egg Globulin.
      - (3) Fibrinogen (coagulated, becomes fibrin).
      - (4) Myosinogen (coagulated, becomes myosin).
  - 2. Combined Proteids.
    - *a.* Hemoglobin — found in the Blood.
    - *b.* Mucins in the Mucous Membrane.
    - *c.* Caseinogen (coagulated by acid, becomes casein).
  - 3. Albuminoids.
    - *a.* Keratin (in membrane of nerves, in horny epidermal cells, hair, and nails).
    - *b.* Elastin (from elastic fibers).
    - *c.* Collagen (connective tissue, cartilage, and bone)— On boiling forms gelatin.
- II. *Carbohydrates.*
  - 1. Simple Sugars (*monosaccharides*).
    - *a.* Grape Sugar (*glucose* or *dextrose*).
    - *b.* Fruit Sugar (*fructose* or *levulose*).
  - 2. Double Sugars (*disaccharides*).
    - *a.* Cane Sugar (*saccharose*).
    - *b.* Milk Sugar (*lactose*).
    - *c.* Malt Sugar (*maltose*).
  - 3. Complex Sugars (*polysaccharides*).
    - *a.* Starch.
    - *b.* Glycogen.
    - *c.* Dextrin.
    - *d.* Cellulose.
- III. *Fats and Oils* (*Ethereal Salts*).
  - 1. Palmitin, 2. Olein, 3. Stearin } (*Esters of Glycerin*).
  - 4. Lecithins (*Esters-like Compounds of Glycero-phosphoric Acid*).
  - 5. Lanolin (*Ester of Cholesterin*). The cholesterins are alcohols.

Alcohol As a Food.— The question of the food value of alcohol is by no means settled. The results of equally skilled experimenters are conflicting, the difficulties to be overcome in solving the problem have not been surmounted, and much is yet to be learned of the digestive action of alcohol. While there is doubt as to its food value, there is no doubt that it is not an economical food; and it has no place in our list of food, as we generally use that term. We shall probably be near the truth to list it as a poison, with doubtful food value. While there is probably no doubt that it can be completely oxidized in the system when taken in moderate doses, it is so strong a nerve poison that it should be given with great care, even in fevers, in which it was formerly thought to be of so great value as a food and to aid digestion. Do not give alcohol or alcoholic drinks when the patient is weak without the advice of a physician, and in every case watch the patient,[1] as it may prove harmful.

Liquid Foods.— Water may be taken alone, or mixed with other substances to flavor or add to its food value by their solution in water. The more important of these are coffee, tea, and chocolate (cocoa). These contain certain aromatic principles, and an alkaloid,— in tea, called *theine;* in coffee, *caffeine;* and in cocoa, *theobromine* (similar to caffeine). In tea, in addition to the theine, there is tannic acid, which acts on the blood vessels, causing their contraction (*astringent*), and lessening the secretions. This action is intensified by the action of the theine, the result of which is a tendency to constipation. Persons suffering from this trouble should use tea very sparingly, and, in fact, would be better without it. Coffee, on the other hand, is free from tannic acid, and with many persons acts as a laxative. Cocoa also contains tannic acid, and, in addition to the substances found in coffee and tea, it contains fat, albuminous matter, and starch, and is, therefore, more of a food.

[1] "If the pulse becomes quick and feeble, or, as indicating gastric irritation, the tongue becomes dry and brown, or the skin hot and dry, or the breathing hurried, or the patient suffers from insomnia, the alcohol should be stopped. On the other hand, if the pulse becomes stronger and slower, the tongue and skin moist, the breathing tranquil, and the patient sleeps well, the drug is doing good." —*White and Wilcox.*

Caffeine and theine are cerebral and heart stimulants. The person becomes wakeful, the mental activity and capability for work are increased, and the reasoning power is affected as much as the imagination. It is also believed that in man caffeine increases the power of muscular endurance, and this view seems to be supported by the results of the use of coffee in the army and navy. These drinks, however, should be used with moderation, as their immoderate use, more especially in the case of tea, will injure the heart and nervous systems, and produce dyspepsia.

CHAPTER IX.

THE CIRCULATORY SYSTEM.

EXPERIMENTS AND DEMONSTRATIONS.

A. Materials.

1. Sharp knife. 2. Probe. 3. Cotton or rags. 4. Fresh specimen of sheep's or ox's heart and lungs, showing the pericardium unbroken, and also part of the diaphragm.

B. Terms.

1. Dorsal, side of heart turned toward vertebral column. 2. Ventral, side next to sternum. 3. Right and left, proper right and left side of the heart when in natural position. 4. Anterior, toward the head in the natural position of the parts. 5. Posterior, the parts turned away from the head.

C. Method.

I. Hold up specimen by windpipe (trachea) so that you can best view the heart; notice the relation of the heart to, 1. Lungs. 2. Diaphragm. 3. The manner in which the sac (pericardium) invests the heart.

II. Place specimen on table with ventral side uppermost, and carefully dissect away fat, etc.

Trace vessels, the one on the abdominal side of the diaphragm to where it enters the pericardium. In order to do this,—

1. Turn right lung toward your left. 2. Turn heart toward your right. 3. Notice entrance into pericardium about three inches from where it enters the diaphragm.

a. This vessel is a vein (*vena cava inferior*). As soon as a vessel is found, clean it, and stuff it.

b. The one which comes from above enters the pericardium about an inch above vena cava inferior. This vessel is also a vein (*vena cava superior*).

c. The vessels between the venæ cavæ coming from the right lung enter the pericardium. Trace the vessels as far as you can from the heart to the right lung. These are the two *right pulmonary veins.*

III. Turn right lung and heart back to natural position.

Clean away loose fat from the front of pericardium, and seek and clean the following vessels in the mass of tissue lying anterior to the heart, on the ventral side of trachea.

1. The one which, immediately on leaving the pericardium, gives off a large branch; then arches back and runs down behind the heart (*the aorta*).

2. The one imbedded in fat on dorsal side of aorta (*pulmonary artery*). Trace its course. Notice nature of the walls of the last-mentioned vessels.

IV. Slit open the pericardium. Notice the surface thus exposed. Then cut away the pericardium from the entrance of the various vessels already traced.

The one on the ventral side of the pulmonary artery (*left pulmonary vein*). Trace this vessel.

V. Notice position of pulmonary artery and aorta. Very carefully dissect out the pulmonary veins in the heart. Note the following: —

1. Upper flabby portion into which the veins open (*auricular portion*).

2. The denser lower part (*ventricular portion*).

3. Look for band of fat running around the top of the ventricles, a branch of which runs obliquely down to the front of the heart, passing to the right of its apex, and indicating externally the position of the internal partition of septum which separates the right ventricle, which does not reach the apex of the heart, from the left, which does.

4. Note the fleshy appendages, one below the pulmonary artery (*left auricular appendage*), the other between the aorta and superior vena cava (*right auricular appendage*).

VI. Dissect away very carefully the fat around the great arterial trunks and base ventricles. Look for —

1. A branch arising from the aorta close to the heart, opposite the right border of the pulmonary (*right coronary artery*). Trace its branches.

The groove which one of its branches follows marks the line between the right auricle and the ventricle.

2. The other much larger arising from the aorta dorsal to the pulmonary artery (*left coronary artery*). Its main branch marks the ventral edge of the ventricular septum.

3. The veins which accompany the coronary arteries (*coronary veins*).

VII. Open right ventricle by placing knife through the heart about an inch from the upper border of the ventricle, and on the right of the band of fat marking the limits of the ventricles (see previous article), and cut down to the apex, keeping to the right of the line; cut off the pulmonary artery about an inch from its origin from the heart.

1. Open the right auricle by cutting a bit out of its walls to the left of the entrance of the vena cava.

2. On raising up by its point the wedge-shaped flap cut from the wall of the ventricles, look for cavity of the ventricle, which examine with care.

a. Pass handle of probe from ventricle into pulmonary artery. Mark thoroughly the relation. *b.* Slit open the auricular appendages, and notice —

(1) Fleshy projections (*columnæ carnæ*).

(2) Nature of the rest of the surface. Note numerous small openings (*foramina Thebesii*).

(3) Apertures of the vena cava.

(4) Below the entrance of the inferior vena cava notice opening of coronary sinuses; pass probe through and along the sinus, and slit it open; notice muscular layer covering it. Raise the flap by its apex, and cut out the ventricular wall, and if necessary prolong the cut more toward the base, until divisions of the auriculo-ventricular valves (the *tricuspids*) come in view. Examine closely, and notice —

(*a*) Muscular cord stretched across its cavity (not found in human heart).

(*b*) Prolongation of the ventricular cavity toward the aperture of the pulmonary artery.

(5) Cut away the right auricle and examine carefully the tricuspid valves. Notice —

(*a*) Tendinous cords (*chordæ tendineæ*).

(*b*) Attachment to ventricle walls (*musculi papillares*), which are attached by one extremity to the walls of ventricles, the opposite extremity giving attachment to chordæ tendineæ.

(*c*) Examine valves of pulmonary artery (*semilunar valves*).

(*d*) Notice in the middle of the free edge of the semilunar valves a little nodule (*corpus aurantii*).

VIII. Open left ventricle in a manner similar to that employed for the right.

1. Open left auricle by cutting a bit out of its walls above the appendage.

2. Cut the aorta off, about half an inch from its origin from the heart.

3. Examine,

a. Aperture between left auricle and ventricle (*left ventricular opening*).

b. Passage from ventricle to aorta.

c. Entry of pulmonary veins to left auricle.

d. Partition (*septum*) between.

e. Auricles.

f. Ventricles.

4. Pass handle of probe,

a. From ventricle into auricle.

b. Another from ventricle into aorta.

c. Probe into points of entrance of pulmonary veins. Notice that no other veins enter this auricle.

d. Slit open the auricular appendage; notice fleshy projection (*musculi pectinati*).

(1) On interior of auricle.

(2) Those over the inner surface of the ventricular wall.

(3) Smoothness of the rest of the surface of auricle.

(4) Thickness of ventricular wall as compared with right ventricle or auricles.

5. Carefully raise wedge-shaped flap of the left ventricle, and cut on toward the base of the heart until the valve (*mitral*) between auricle and ventricle is brought to view.

a. Notice,

(1) Position of the flaps. (2) Texture. (3) Chordæ tendineæ. (4) Columnæ carneæ, etc., as in case of right side. (5) Semilunar valves of aorta.

b. Cutting up carefully between two of them, examine the bit of aorta still left attached to heart.

c. Note the origin of the coronary arteries in two of the three dilations (*sinuses of Valsalva*) of the aorta wall above the semilunar flaps.

IX. Examine piece of aorta, and notice,

1. Thickness of its walls. 2. Extensibility in all direc-

tions. 3. Its elasticity. 4. That it does not collapse when empty.

X. Examine piece of a vein, and compare structure with that of the artery. How do the pulmonary artery and aorta compare with the venæ cavæ and the pulmonary veins in their structure and properties? How can you account for this difference? Does a transverse section under the microscope show any difference in structure? Why should the arteries differ in their structure from the veins?

Heart Muscle Cell.— Take a small piece of a fresh specimen of the heart. Tease in normal salt solution (six-tenths per cent salt) until in very fine threads. Examine with microscope, first with two-thirds objective and then with one-sixth objective. Make careful drawing of what you observe. Notice,

1. That it has no sarcolemma.
2. That the cells anastomose (define the last term).

Queries. — 1. Where is the coronary valve, and what is its function?

2. What is the difference in structure of the heart of an earthworm, a snail, a fish, a snake, a bird, and a mammal?

3. What animals contain a nodule of bone in the heart? Where? Why?

4. What animals have blood but no heart?

5. How many hearts has the earthworm?

6. Compare structure of a cell of heart muscle, of voluntary and of involuntary muscular fiber.

TO SHOW THE GENERAL PRINCIPLE OF CIRCULATION.

1. Apparatus.— A bulb syringe; two yards of elastic rubber tubing; two yards of inelastic rubber tubing; short pieces of glass tubing of different sizes, some drawn out into short jets, others into long ones of almost capillary bore, and a basin of water.

2. Manipulation. — Attach to one end of the syringe the inelastic tubing; now place the other end of the syringe in the water. Press upon the bulb, release the pressure, repeat the process until the tube is full of water. Press forcibly upon the bulb, and see how far you can send the water. Is

the stream constant? In the experiment, to what would the bulb correspond? The pressure upon the bulb? The release upon the bulb? The alternate spurting? Place the finger lightly upon the tube when water is being forced through it by the bulb. Do you feel anything that corresponds to the pulse in the arteries?

Now try similar experiments by putting in the opposite end of the tube one of the jet tubes. Repeat the experiment with various tubes. Note carefully any change that may be made in the force or constancy of the stream due to the size or length of jet.

Repeat the experiments, but use instead of the inelastic tube, the elastic tube.

Note change in constancy of the stream when the jet tubes are used; also the more marked pulse movement. From these experiments we may learn,

a. That the contraction of the heart (*systole of the ventricle*) forces at intervals a quantity of blood with a certain force into the aorta. The bulb representing the heart; the tube, the aorta.

b. By the blood vessels becoming smaller, there is offered to this force a resistance (*peripheral resistance*) as the arteries become smaller, lessened when their bore is increased by relaxation of their muscular coats. In the experiment of jets of different sizes, illustrate the cause of this resistance, also the effect of increase of size of vessels.

c. The arteries being elastic, we have a long stretch of elastic tubing from the heart to the capillaries. As in the experiment, so in our bodies, these elastic tubes give constancy to the flow.

d. By connecting with the main elastic tube a three-way tube, to which is attached elastic tubes ending in jet tubes, it will be learned that the greater amount of fluid will flow in the tube in which the peripheral resistance is the least; i.e., through the tube having the largest opening. So it will be in the arteries. If in any part of the body the peripheral resistance is increased by the contraction of the

muscular coat of the artery, and the resistance of another part of the body lessened by the relaxation of the muscular coat, the blood will flow from the region of great resistance to that of small resistance.

Queries.— 1. Why should fear cause an increase of the heart's beat?

2. What physiological fact does blushing illustrate? Growing pale? Give reason for the difference.

3. Why is there more blood in the digestive organs during digestion?

4. Are the blood vessels of the digestive organs in a state of relaxation or contraction?

1. The Arteries.— If you have an injection apparatus, inject the aorta from the left ventricle. To do this, before killing the cat or rabbit determine the position of the heart by the beat upon the thoracic wall. After killing, make an incision to the left of the sternum, and at such a level as will be most convenient to reach the left ventricle. The left ventricle may be told from the right by its firmer walls. Make an incision in the left ventricle large enough to admit the canula. Force the canula up into the aorta, and tie firmly in position by thread wrapped around the aorta. Now fasten to the canula the piece with the stop-cock. Before injection clean the part from blood by the use of a moist sponge. Fill the syringe with injection mass (see Injection Mass below), place in the piece with stop-cock, which should be open, and press gradually upon the piston until the syringe is emptied; before removing the pressure, close the stop-cock so as to keep the mass in the arteries. Repeat the process until the injection mass gives color to the very small arteries.

2. The Veins.— Prepare another cat or rabbit ready for dissection. Remove the skin from the thigh, and on the inner side, between the two great muscles of this part, look for a large vein (*femoral*). Ligature the vein in two places about an inch apart. Make an incision large enough to admit a small canula. Insert canula so as to point toward the heart, and tie firmly in place, and cut the upper ligature. Inject in the same manner as you did the artery.

Carefully dissect out the vessels, using great care in the separation of tissues and muscles.

3. The Capillaries.— Catch a tadpole, and dehydrate by putting in sixty per cent alcohol for two hours, then in seventy-five or eighty per cent. Then color by putting in hæmatoxylin for eight or ten hours. Again put in alcohol ninety to ninety-five per cent, then in turpentine, and mount in dammar. Use two-thirds objective and eyepiece. Examine also with one-fifth objective.

4. Injection Mass.— One of the best injection masses is made as follows: —

1. Make a solution of dichromate of potash, about half a pint.

2. Add to the solution a solution of acetate of lead as long as a precipitate is formed. Let the precipitate settle.

3. Pour off the fluid from the precipitate, and wash the precipitate until it is free from acid. To do this, add water to the precipitate, stir thoroughly, let it settle, and pour off the fluid. Repeat as often as is necessary.

4. To about three pints of water placed in a vessel over a water bath, add white glue, and heat until the mass has the consistency of a thin gravy.

5. Now add enough of the precipitate to give the mass a bright yellow color. Set away to cool. Warm before using, and keep warm while using.

5. Queries.— 1. From what has been given trace the circulation of the blood from the right auricle to the left ventricle; from the left ventricle to the right auricle. How do these circulations differ (*a*) in the color of the blood which flows through the arteries and veins and (*b*) in their purpose?

2. What artery carries venous blood, and what vein arterial blood?

3. What large blood vessels would be cut by an amputation of the lower limb just below the knee? In the amputation of the arm above the elbow?

4. Trace the blood from the left auricle to the palm of the hand and back to the right auricle, naming the large vessels through which it would pass (see chart).

5. Why can you not inject the veins from the right auricle? How much of the venous system can be injected from the femoral vein? Give reason for your answer.

6. In what part of the body does the blood have to pass through a double system of capillaries before it returns to the heart?

7. What veins end in capillaries?

8. In case of a wound, how can you tell an artery from a vein? What difference should be made in the application of pressure to prevent bleeding? Why?

6. To Make a Permanent Mount of Blood.—Take a clean slide; near the center spread on very thinly a small amount of freshly drawn blood; gently warm over an alcohol flame, until dry (avoid getting too hot). When the slide has cooled, make a ring of Bismarck black of the size of the cover; let ring dry; when dry, gently heat the slide from the side opposite the ring; now carefully put on the cover glass (do not heat too much, only enough to make the cover glass adhere to the ring).

7. To Examine the Blood, Fresh.— Spread on the slide a small amount of blood, and then put on the cover glass. The thinner the layer of blood the better view you will have of the corpuscles.

Examine blood of different animals; make drawings of what you observe.

1. When you kill a chicken, collect the blood; divide it into two portions; set the first away, and notice at intervals of a few minutes any changes that may take place. Stir the second portion with a bunch of wires or twigs. In a short time the fibrin will collect on the wires, and if the process is continued all the fibrin may be removed. The fibrin thus obtained will be red from the corpuscles; these may be removed by washing in water, and when clean, the fibrin will be white and in the form of highly elastic threads. After the fibrin has been removed, the blood is called defibrinated blood.

2. If platinum wire or foil can be obtained, dip one end in the freshly drawn blood, then hold it in the alcohol flame for a short time, when it will become coated with black, showing the presence of carbon in the blood. Continue to hold it in the flame, and finally notice that an ash will be

left on the wire, showing the presence of the mineral constituents.

3. To a drop of blood, add a drop of acetic acid and examine with the microscope; to another drop on the slide, add some fresh water, and carefully note with the microscope the change in size, and to the third, add some alcohol, and examine as before. Give reasons for each of the above changes of shape and size of the corpuscles. Make drawings.

4. Take from a sore some of the matter, and examine for colorless corpuscles. Make drawing for any change of form that may be observed.

In any of the above experiments, where it is desired to have the corpuscles retain the vitality, it is best to keep them moistened with a normal salt solution (six-tenths per cent) and let the slide be kept warm, as directed in Appendix.

8. The Circulation of the Blood.—Take a piece of a thin board, as a chalk-box lid, and cut in it near one end, a triangular hole an inch on a side. Obtain a frog, and holding it firmly in the left hand, make with scalpel a small incision in the skin on top of the head; now insert beneath the skin a piece of *urari*[1] about one fourth the size of a pin head. Let the frog free in the room, and in a few minutes it will be ready for use. The poison paralyzes[2] the voluntary muscles, but seems to have little effect at first upon the involuntary muscles, hence respiration and circulation will be normal or nearly so. Place the frog upon the thin board, and tie the web over the hole by means of threads attached to the toes. The threads may be held in place by slits cut inside of board or by small tacks driven in edges of the board. Place the board on stage of microscope so that the web may be illuminated by the mirror below the stage, and brought in focus with the objective

[1] Urari (Indian arrow poison) is very poisonous, and should not be handled if the skin on the hand is in any way broken, as it may be absorbed by the blood and produce poisoning. To remove the urari from the scalpel, soak it in dilute alcohol. *Always remove the urari from the scalpel after the experiment.*

[2] More properly speaking, the poison paralyzes the end plates of the nerves rather than the muscle or the entire nerve, or the center from which it comes. In the involuntary muscles, nerve endings are paralyzed and death is produced by paralysis of respiration. If, however, the dose is not too large, the excretory organs will carry off the poison, and the animal will recover. The drug is also called curara, woorara.

above. Use a three-fourths objective. Cover the frog over with a moist cloth, leaving only the web exposed. *Remember urari is very poisonous, and must be used with the greatest care.*

Notice carefully the rate and mode of the circulation. Do you notice any change in the form of the red corpuscles? Why are they not red?

Good results may be secured without the use of urari, by simply tying the frog firmly over the body by a band of cloth.

Another very good method is to put salamanders into a clean glass jar, and place the jar in a strong light. Cause the salamanders to crawl up the sides of the jar and as the webs are spread out on sides of the jar before you, you can examine with reading glass or simple microscope lens (50 or 60 diameters). This is worth trying, as you will be able to view the circulation under normal conditions.

CIRCULATION.— TEXT.

Position of the Heart.— The heart (Fig. 128) is situated in the thoracic cavity in the space between the lungs, and is placed obliquely. The base, or attached portion, is directed upward, backward, and to the right; the apex, forward, downward, and to the left. It is placed behind the lower two thirds of the sternum, and projects farther to the left than to the right, and one and a half inches to the right. It extends (Fig. 128) from the second to the space between the fifth and sixth ribs.

The Pericardium.— The heart is invested by a fibro-serous membrane, the *pericardium.* The sac is conical in shape, with its apex above, where it surrounds the great blood vessels about two inches from their origin. Its base is attached to the central tendon and part of the adjoining muscular structure of the diaphragm. Behind it are the bronchi, the esophagus, and descending aorta. Laterally descending between it and the pleura is the phrenic nerve.

The pericardium consists of two layers. The outer (*fibrous*) is a strong, dense membrane. Above, it invests,

by a tubular prolongation, the large blood vessels, which have their origin from the heart, and becomes gradually lost upon their external coats. The inner (*serous*) invests the heart, and is then reflected on the surface of the fibrous layer.

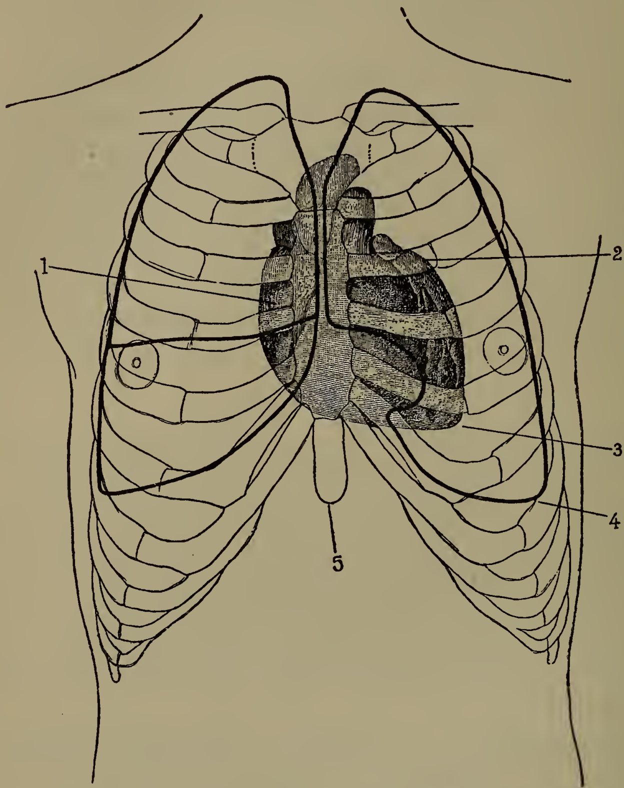


FIG. 128.—POSITION OF THE HEART.

1. The heart. 2. Third costal cartilage. 3. Fifth intercostal space. 4. Black line marks the outline of the lungs. 5. Sternum.

Parts of the Heart.—The heart is a double organ (Figs. 129 and 130), separated by a muscular septum into the right and left sides. Each half is divided by a constriction into an upper portion (*auricle*) and a lower portion (*ventricle*). This division is indicated by the transverse groove (*auriculo-ventricular*).

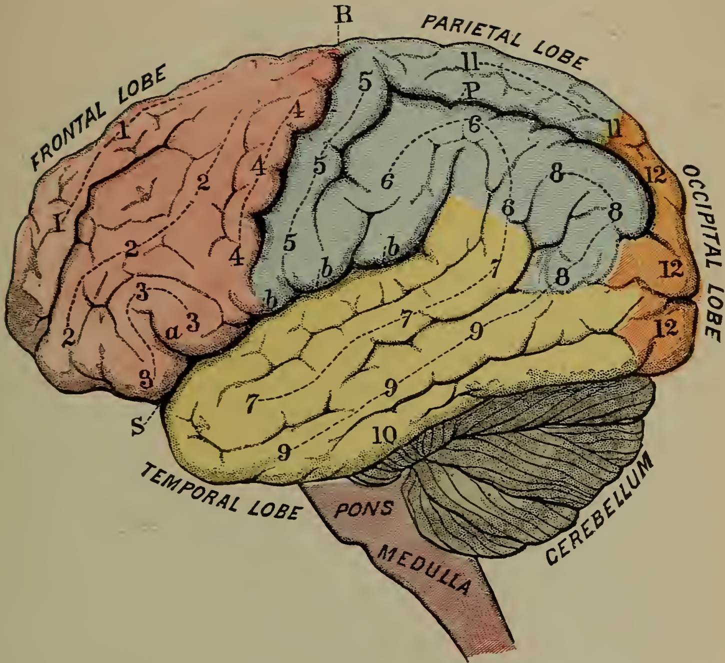


PLATE XI.

FIG. 76.—A DIAGRAMMATIC FIGURE SHOWING THE CEREBRAL CONVOLUTIONS. (Modified from Dalton.) (From Ranney.)

S. Fissure of Sylvius, with its two branches, *a*, and *b*, *b*, *b*. R. Fissure of Rolando. P. Parieto-occipital fissure. 1, 1, 1. The first, or superior frontal convolution. 2, 2, 2, 2. The second, or middle frontal convolution. 3, 3, 3. The third frontal convolution, curving around the ascending limb of the fissure of Sylvius (center of speech movements). 4, 4, 4. Ascending frontal (anterior central) convolution. 5, 5, 5, Ascending parietal (posterior central) convolution. 6, 6, 6. Supra-Sylvian convolution, which is continuous with 7, 7, 7, the first or superior temporal convolution. 8, 8, 8. The angular convolution (or gyrus), which becomes continuous with 9, 9, 9, the middle temporal convolution. 10. The third, or inferior temporal convolution. 11, 11, The superior parietal convolution. 12, 12, 12. The superior, middle, and inferior occipital convolutions, called also the first, second, and third (the centers of vision). It is to be remembered that the term "gyrus" is synonymous with "convolution," and that both terms are often interchanged.

Openings of the Heart.— The openings of the heart are:—

1. *To the Auricles.*— *a.* The right: the vena cava superior, vena cava inferior, coronary sinus, and venæ thebesii. *b.* The left: the four pulmonary veins, entering the heart by two trunks.

2. *From the Ventricles.*— *a.* From the *right* ventricle, the pulmonary artery. *b.* From the *left* ventricle, the aorta.

3. *Within the heart,* between the auricles and ventricles, the *auriculo-ventricular orifice.*

Valves of the Heart.— 1. Between auricles and ventricles (*auriculo-ventricular*). *a. On the right side,* the *tricuspid,* formed by a duplicating of the lining membrane of the heart, strengthened by a layer of fibers containing, according to some authorities, muscular fibers. They consist of three segments of triangular shape, which are connected by their bases and by their sides with one another, so as to form a continuous annular membrane. To their free margins and their lower surface are attached the delicate tendinous cords (*chordæ tendineæ*) extending to some of the muscular projections (*musculi papillaries*) from the wall of the ventricles. *b. On left side,* the *bicuspid,* or *mitral.* It is similar in attachment and structure to the tricuspid, but stronger and larger, and consists of two segments of unequal size. The tendinous cords are thicker and stronger, but fewer in number. Notice the various ways by which greater strength is given to the left ventricle.

2. In blood vessels going from the ventricles — the *semilunar* valves. *a.* Pulmonary valves. These are two in number (by some authorities three), formed by the duplication of the lining membrane of the heart, strengthened by fibrous tissue. They are attached by their bases so as to form pocket-like valves. In the center of the free edge of the valves is a small, fibrous nodule (*corpus Arantii*). *b.* Aortic valves. These are three in number, and they are similar in structure to the pulmonic, but are larger, stronger, thicker, and the markings on the surface (fibers from the corpus Arantii)

are larger and more prominent than those of the right side of the heart.[1]

Structure of the Walls of the Heart.— The walls of the heart are muscular, and made of fibers having a very complex arrangement. They may, however, be put into two classes: (1) Those of the auricles, which are arranged in two layers, — a superficial layer common to both auricles; a deep-seated layer, proper to each auricle, consisting of looped fibers passing upward over each auricle. Annular fibers surround the whole of the auricular appendage and are continued on the

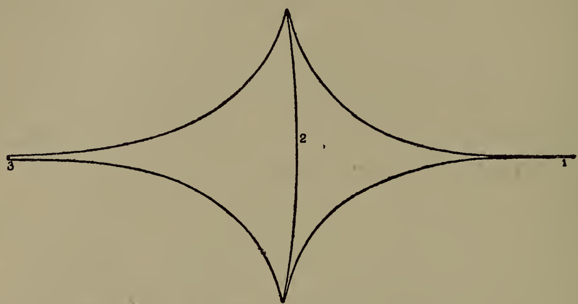


FIG. 132.—RELATIVE AREA OF THE AORTA, TOTAL CALIBER OF CAPILLARIES AND VENÆ CAVÆ.
1. Aorta. 2. Total caliber of capillaries. 3. Venæ cavæ.

walls of the vessels which have their origin from the auricles. (2) Those of the ventricles. These are arranged in numerous layers. Their arrangement is very complex. The general direction of the external layers is nearly inclined from left to right as they run downward, while that of the internal is just the reverse, nearly vertical, running upward from left to right.

These muscular walls are covered on their pericardial surface by the cellular layer, on the inner surface by the endocardium, which by its reduplication assists in forming

[1] In addition to the valves mentioned there are the following:—

1. The imperfect valve (Eustachian) at the mouth of the inferior vena cava, which in the adult serves no very important purpose, but in the first stages of the individual, serves an important function in directing the blood through tho *foramen ovale.*

2. The valves of the coronary veins, which, to a degree, prevent the reflux of the blood into these veins during the contraction of the auricles,

the valves, and is continuous with the linings of the great blood vessels. On the internal surface of the auricular appendages are muscular columns (*musculi pectinati*). From nearly the whole inner surface of the ventricles project rounded muscular columns (*columnæ carneæ*). The muscular walls of the left side are much thicker than those of the right side.

Size and Weight of the Heart.– In the adult the heart is about five inches in length, and three and a half in breadth in the broadest part, and two and a half inches in thickness. The average weight, in the male, varies from ten to twelve ounces; in the female, from eight to ten ounces. The proportion to body weight is 1 to 169 in the male, and in the female, 1 to 149 (Gray). The heart continues to increase in weight and size up to an advanced age. This increase is more marked in men than in women.

Nutrition of the Heart.— The heart is nourished by the coronary arteries, which arise from the aorta, just above the free margin of the semilunar valves, the right coronary artery going to the right border and the left going to the left border. It arises a little higher than the right, and is somewhat larger. Why should it be larger? These arteries break up into numerous branches over the surface and substance of the heart. The veins of the heart accompany the arteries. The veins are the great cardiac vein, the anterior, middle, and posterior cardiac veins, and numerous small veins (*venæ cordis minimæ*), which enter the heart by independent openings (*foramina Thebessi*).

Nerves of the Heart.— The nerves are derived from the cardiac plexus. The nerve cells, or ganglia, are distributed at the junction of the sinus with the auricle and also along the entering nerve (*sinus ganglia*) at the junction of the auricle and ventricle. There are also ganglia found on the auricle. In addition to these ganglia, the heart receives nerve fibers from the *pneumogastric nerve* (*par vagum*), which gives to the heart *augmentory* and *inhibitory fibers.*[1]

[1] In the dog it has been found that the augmentory fibers leave the spinal cord by the anterior roots of the second and third dorsal nerves, and possibly,

Arteries.—The wall of the small artery (Fig. 133) which is soon to break up into capilliaries consists of,

1. An inner lining of cells similar to that making up the wall of the capillary, resting upon a thin, transparent, structureless membrane (basement membrane).

2. A layer made up of connective tissue in which are imbedded muscular fibers (middle or muscular coats).

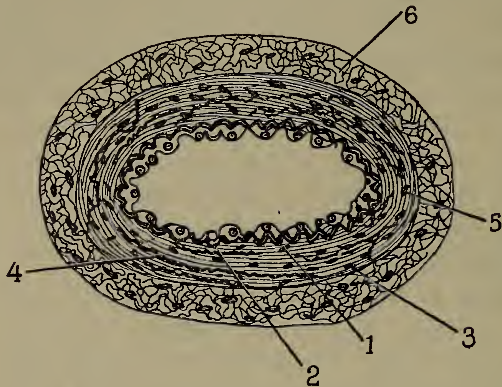


FIG. 133.—SECTION OF AN ARTERY OF A CAT.

1. Endothelial layer. 2. Inner layer (intima). 3. Nucleus of muscular cells of middle coat. 4. Elastic fibers. 5. Middle coat (tunica media). 6. Outer coat (tunica adventitia). (C. W. B.)

3. A layer of connective tissue containing a relatively large number of elastic fibers (external coat).

It will be seen that the effect of this increase of thickness is to render the walls of the artery less permeable, and the power of the interchange of materials through its walls is to a great degree lost.

When the artery breaks up into capillaries, these coats disappear, the muscular coats sometimes continue for a short distance, and all that is left of the outer coat is a little connective tissue.

---

to some extent, by the fourth and fifth, passing along the rami communicans into the stellate ganglia, and passing upward through the annulus of Gimssens to the inferior cervical ganglia, and thence along cardiac to the superior vena cava and heart. The inhibitory fibers which come by way of the spinal accessory, pass through the ganglion (*trunci vagi*), along the trunk of the vagus, and by branches to the superior vena cava and the heart.

The larger arteries[1] resemble the small arteries in so far that their walls may be considered as composed of three coats, but each of these coats is of a more or less complex nature, and the minor details of their structure differ in different arteries.

It should be observed, however, that as a general rule, the muscular fibers in the small arteries bear a larger proportion to the elastic than to the larger arteries.

The Capillaries. — If we examine the various tissues of the body, we shall find that, with some few exceptions, they are traversed with a network of very small tubes (*capillaries*) which surround the elements of the tissues. This is beautifully shown by the microscopic examination of an injected specimen of voluntary muscles (Fig. 134) or the web of a frog's foot.

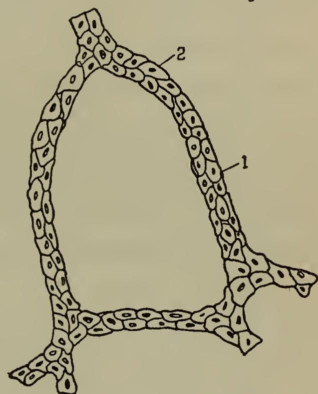


FIG. 134. — CAPILLARIES, TAIL OF TADPOLE.

1. Endothelial cells. 2. Nucleus. Notice the joining of the branches (anastomosis). (Brinckley C. W. B.)

These little tubes, although very small, vary in size, from that so small that one red corpuscle can with difficulty pass, to that in which three or four may pass abreast. The size, too, of the capillary will vary with blood pressure.

The walls of the true capillaries are very thin, consisting of a single layer of spindle-shaped cells cemented together so as to form a tube. It is in these small tubes that the work of the interchange of the materials between blood and tissues takes place. Through these thin walls the blood may give to the cells of the tissues the materials they need for their nutrition and work, and the cells may give back the waste

1 The larger arteries are, as a rule, deep-seated, being superficial at only a few points, as at the wrist, the temples, the popliteal space, and the ankle. At these points they are so near the surface that their pulsation may be felt. The radial artery is generally taken to determine the pulse. The large arteries are accompanied by one or more large veins called the *venæ comites*.

product of its activities as carbon dioxide, etc., to the blood.

It is in these little tubes and the minute capillaries that the great work of the blood takes place.

The walls of the other blood vessels are too thick for the blood to pass through.

In many parts of the body these little tubes are so numerous that the tissues could not be pierced by a needle without touching one of them. Coming to these from the heart are a system of tubes (*arteries*), furnishing the channels wherein to send a supply of blood to the capillaries.

Going from them to the heart is another system of vessels (*veins*), furnishing the channels for the drainage of the waste products of the cell activities.

The Veins.— These vary in different parts of the body so very widely that it is very difficult to give a general description of a structure suitable to all veins.

It may be said, however, that they differ from the arteries in having much thinner walls; and these walls containing relatively much more white connective tissue and much less yellow elastic tissue, muscular fibers are found in a larger or smaller proportion.

Valves.— Many of the veins are provided with pouch-like folds of the inner coat. The mouth of the valve is directed from the capillary toward the heart. These are so placed that in case of re-flow of the blood, it will be stopped by the valve. The onward pressure of the blood by means of the valves causes the blood to be lifted against gravity.

The valves are absent in the viscera and in those veins in which the blood is not forced to flow against gravity. They are therefore found in greatest number in the extremities. The more important veins without valves are the venæ cavæ, hepatic, portal, renal, spinal, cerebral, and pulmonary.

As the arteries divide, their united caliber increases so that the channels for the blood flowing from the heart may be represented by a funnel (Fig. 132) with wide portion direct from the heart. On the other hand, the veins unite

to form larger ones, and the united caliber become less, so that they could be represented by a funnel with small portion direct toward the heart. This increased and decreased caliber has a great influence upon the rate of flow of blood in different parts of the body.

It is important to remember that the total capacity of the veins far exceeds that of the arteries. Indeed, nearly the entire quantity of blood may be forced into the portal vein and its branches. The united sectional area of the capillaries is about four hundred times that of the aorta.

The elasticity and the muscular elements of the middle coat are very important factors in determining the constancy of the flow of the blood, and in regulating the blood pressure. We have seen that the arteries and veins are capable of increasing their caliber. The question might naturally arise, "Is there any way in which their size may be regulated?" There are times when the heart must do more work than at others. Can its beat be so regulated as to enable it to do the extra work? The above questions are almost too difficult to treat in the present work, but there are a few principles we must know, even to have an elementary knowledge of circulation.

The muscular fibers of the arteries and veins are provided with two kinds of nerve fibers (*vasomotor nerves*) (Fig. 135), one causing the contraction of the muscular fibers (*vaso-constrictors*) coming from the spinal cord through the sympathetic to the artery; the other causing the relaxation of the muscular fibers (*vaso-dilators*), coming from the cranial nerves, and therefore medullated fibers. The former decrease the size of the artery, and the latter increase it. The heart is also governed by two sets of fibers, the *inhibitory fibers* going by means of the spinal accessory from the central nervous system (medullated fibers), and the *augmentory fibers* coming from the anterior roots of the second and third dorsal nerves, but which lose their medulla before they reach the heart. The stimulus of the one and the inhibition of the other could cause an increase in the

heart's beat. The conditions reversed, the result would be a decrease of the heart's beat.

SYSTEMIC CIRCULATION.

Arteries. — From the demonstrations which are given in this article we may learn that there arises from the left ventricle of the heart a great arterial trunk, the *aorta*. At its very base are given off two small arteries, *coronary arteries* (Fig. 129), which go to the heart. The aorta soon curves upward, across, and downward, forming what is called the arch of the aorta; from the right and upper part of the arch is given a branch (*innominate artery*), which soon divides into two branches, one with its branches supplying the head and neck (*right common carotid*), the other (*right subclavian*) passing onward over the axilla of the arms (here called the *axillary artery*), then onward down the arm (*brachial artery*); at the elbow it divides into two branches, one on the radial side (*radial artery*), the other on the ulnar side (*ulnar artery*). From these are given off branches which go to the hand.

From the left and upper part of the arch is given off a branch which with its branches goes to the head and neck (*left common carotid*). A short distance to the left is given off another branch (*left subclavian artery*), which goes to the arm having the same divisions as the corresponding arteries on the right side.

The Aorta now curves downward and backward, keeping very close to the spinal column, and after giving off branches to the walls of the chest and the organs contained in it, passes through the diaphragm into the abdominal cavity. Soon there is given off a branch (*cœliac axis*) which breaks up into three divisions, one going to the stomach (*gastric artery*), another to the spleen (*splenic artery*), and the other to the liver (*hepatic artery*). A short distance below this there is given off a large branch which goes to the small intestine and to part of the large intestine (*superior mesenteric artery*). Just below the superior mesenteric a branch

is given off from the right and left sides of the aorta which goes to the kidney of that side (*renal artery*). About two inches above the division of the aorta, from its left side, is given off a branch which is distributed to a part of the large intestine (*inferior mesenteric*). Near the fourth lumbar vertebra the aorta divides into two great branches (*right common iliac* and *left common iliac*), and these in turn soon divide into two large branches; the inner one (*internal iliac*) going to the pelvic viscera, and the outer (*external iliac*) continuing onward to and down the thigh (*femoral artery*). It then passes downward from the adductor magnus to the popliteus (*popliteal artery*), where it divides into two branches, one going to the front of the leg (*anterior tibial*) and the other continuing downward on the back portion (*posterior tibial*). From these arteries are given off branches which go to the foot. The divisions of the left common iliac are like those of the right.

We should keep in mind the fact that the various arteries divide and subdivide, and finally break up into capillaries. We should also remember that we have mentioned but a few of the many arteries of the body.

Veins.— Arising from the capillary network are the smaller veins which unite to form the larger ones. On the thumb side of the forearm there arises a vein (*radial vein*), which, near the extremity of the forearm above, meets with a short branch to form a vein (*cephalic vein*), which passes upward on the outer surface of the arm, and becomes united with the subclavian vein. Along the median line of the upper surface of the forearm runs another vein, which, near where the forearm reaches its greatest diameter, divides into two short branches, one going to the right (*median cephalic*), joins the cephalic vein; the other (*median basilic*) to the left, joins the basilic vein. On the side of the little finger arise two veins, one on the upper surface (*anterior ulnar*), and the other (*posterior ulnar*) from the lower surface. These unite to form the *common ulnar vein,* which unites with the median basilic to form the *basilic.* These become

more deeply seated in the arm, and join with the deep-seated veins (*brachial veins*) which accompany the brachial artery, forming the *axillary;* this passes over the arm-pit, and continues onward, passing beneath the clavicle, where it changes its name (*subclavian vein*), and continues to near the articulation of the clavicle with the sternum, where it meets a large vein (*external jugular*) coming from the head, and forms with it a short vein (*left innominate vein*), about an inch and a half in length. The right innominate unites with the left to form a large vein (*superior vena cava*), which empties into the right auricle of the heart. The divisions of the left innominate are the same as those of the right.

Arising from the branches of the foot is a large vein (*internal*, or *long saphenius*), which runs along the outer and inner surface of the leg and thigh, joining the femoral vein near the widest part of the thigh. From the outer and upper surfaces of the foot there arises another vein (*external,* or *short saphenius*), which passes upward along the median line, and on the posterior surface of the leg, joins above the knee pit with the popliteal vein. More deeply seated will be found four large veins, two anterior to the tibia (*anterior tibial veins*). These unite to form a large vein (*popliteal vein*), which extends upward from the popliteal space of the lower third of the thigh, changes name (*femoral vein*), becomes larger by receiving numerous veins when it passes through the crural arch (see Gray), where its name is again changed (*external iliac*), and by the union with a branch coming from the pelvic viscera it forms a large vein (*right common iliac*), and then, joining with its fellow on the left, forms the great venous trunk (*inferior vena cava*). From each of the kidneys it receives a vein (*renal veins*), and from the liver three veins (*hepatic veins*). Passing through the diaphragm, it empties into the right auricle of the heart.

In addition to the veins we have mentioned, there is a system of veins coming from the digestive viscera, the stomach, intestines, and spleen; one from a part of the large intes-

tine (*inferior mesenteric*), one from the small intestine and a part of the large intestine (*superior mesenteric*), and one from the spleen (*splenic vein*). By the union of the superior mesenteric and the splenic vein is formed a large vein (*portal vein*), which, after receiving veins from the stomach (*gastric veins*), goes to the liver and breaks up into a system of capillaries. The blood is re-collected by the hepatic veins, and taken to the inferior vena cava.

Pulmonic Circulation. — Arising from the right ventricle of the heart is an arterial trunk (*pulmonary artery*), which soon divides into two branches, one going to the right lung (*right pulmonary artery*), the other to the left lung (*left pulmonary artery*). These break up into the dense network of capillaries of the air cells of the lungs. From these capillaries are formed veins which go to the right to form two veins (*right pulmonary veins*), which in turn go to left auricle of the heart; and on the left, two (*left pulmonary veins* which also go to the left auricle. This circulation is called the pulmonary circulation, or the lesser circulation. Its function is to secure the aëration of the blood. It should be kept in mind that the nutrition of the lungs is accomplished by another system of vessels, the *bronchial veins* and arteries, which are a part of the systemic circulation.

Causes of the Circulation of the Blood.— We cannot give in an elementary treating of this wonderful and complex phenomenon a complete description of why and how the blood flows, nor consider the various conditions which modify its quantity and force. There are, however, general principles with which we should become acquainted: —

1. That the great propelling force of the circulation is the ventricular contraction of the heart. This force alone is sufficient to force the blood from the aorta through arteries, capillaries, and veins to the right auricle, or from the pulmonary artery to the left auricle.

2. That the other forces, as resistance offered by the size of the capillaries, the muscular coats of the arteries, and the veins, the elasticity of the arteries, the pressure due to the

contraction of skeletal muscles, in connection with the valves of the veins, which prevent a backward flow, the influence of respiration, and the force of gravity, are not causes of circulation, but only forces which modify the effect of the propelling force of the ventricular contraction.

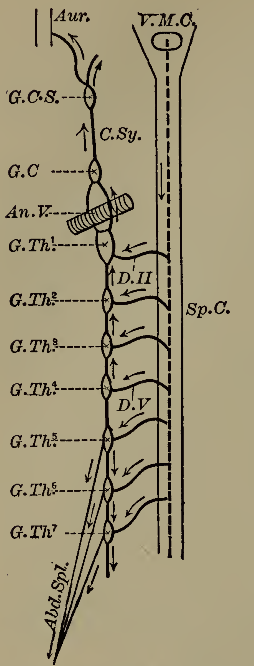


FIG. 135.—DIAGRAM OF VASO-CONSTRICTOR FIBERS OF CERVICAL SYMPATHETIC AND PART OF THE ABDOMINAL SPLANCHNIC NERVE.

Aur. Artery of the ear. *G. C. S.* Superior cervical ganglion. *Abd. Spl.* Abdominal splanchnic. *V. M. C.* Vaso-motor center in medulla. *G. Th.*1, *G. Th.*2, *G. Th.*3, etc. The respective thoracic ganglion. *Sp. C.* The spinal cord. The dotted line represents the course of the vaso-constrictor impulses down the cord from the vasomotor center. *An. V.* Annulus of Vieussens. *D. II* and *D. V.* The respective spinal nerve. *C. Sy.* Cervical sympathetic.

The great engine which forces the blood in its ceaseless round through artery, capillary, and vein is the heart.

The rate and the quantity of the flow will depend upon the rapidity and energy of the heart beat and the peripheral resistance. The heart's contraction is due to the metabolic changes taking place in the heart muscle, and the heart contains within itself the stimulus for its contraction. In the embryonic heart there are no ganglia, and yet the heart beats rhythmically; the heart's beat is therefore independent of the influence from its ganglia.

The force and frequency of the heart beat is under the influence of the central nervous system. The stimulus from the two vagi tends to lessen the rate of the heart beat (*inhibit*), while the stimulus from the sympathetic nerve tends to increase the frequency of the heart beat (*accelerate*). The fibers from the vagi are called the *inhibitory nerve,* and that from the sympathetic system the *acceleratory nerve.* Under normal condition their stimulus is tonic, but if the inhibitory stimulus is increased, the heart beat is retarded;

if the acceleratory stimulus is increased, the force and frequency of the beat is increased.

The direction of the flow of excess of blood will be determined by the peripheral resistance, and will be toward the region of least resistance. The resistance is regulated by the muscular coat of the arteries. If the cutaneous arteries are contracted, and those of the viscera relaxed, the greater amount of blood will flow to the viscera. If, however, those of the viscera be contracted, while those of the skin are relaxed, the flow will be from the viscera to the skin.

The constancy of the flow is due to the peripheral resistance and the elasticity of the artery walls.

How the Heart Contracts.—The right auricle during the relaxation (*diastole*) of its muscular fibers, and by the fact that all backward pressure from the ventricles is removed by the closing of the tricuspid valves, offers but little resistance to the flow of blood from the veins. The blood in the veins is under pressure, which, though diminishing toward the heart, remains greater than that within the auricles. As a result, the blood flows into the empty auricle, and in case of the superior vena cava is assisted by gravity. At each inspiration this flow is favored by the decrease of pressure on the heart and great vessels caused by respiratory movements. Before this flow has gone very long the relaxation (diastole) of the ventricle begins; the cavity dilates, and the flaps of the tricuspid fall back, and the blood for a short time flows in a continuous stream into the ventricle. It is not long, however, until the ventricle is two thirds full, when a short, sharp contraction (*systole*) of the auricle completes the filling of the ventricle. It will be noticed, however, that the systole begins in the great vessels and descends into the heart. The force of the contraction is spent sending the blood into the ventricle, where the blood pressure is still less than it is in the veins. The ventricle being filled by the auricular systole, the systole of the ventricle almost immediately follows.

Let us keep in mind the fact that the blood in the pulmonary artery is under pressure by the tension of the elastic

arteries, and is pressing upon the semilunar valves as well as upon the capillaries and veins. When the ventricles are full, the pressure becomes equal on each side of the valves, but as the ventricle continues to contract, the pressure from the blood in the ventricle becomes greater than that of the blood in the arteries, and the blood is sent with a bound into the pulmonary artery. So completely is this done that the walls of the ventricle come in contact, and all the blood is forced out. As soon as the ventricle begins to relax, there being no longer pressure from the ventricle, the blood presses back upon the semilunar valves, and closes them. During the whole of this time the left side has, with still greater energy, been executing the same movements.

Each auricle contracts at the same time, but the contraction of the left auricle is stronger than that of the right. Close upon the contraction of the auricles follows the systole of the ventricles, which, like the auricles, takes place at the same time, but the right contracts with much greater force? Why?

After the systole of the auricle and ventricle, there is a short passive period (*the rest of the heart*), in which there is neither contraction nor relaxation.

The diastole and systole of the auricles and ventricles, and the passive interval, taken together make the *cardiac cycle, or heart beat,* which in a heart beating seventy-two times a minute lasts for .08 second. The ventricular contraction lasts about .03 second, the passive interval about .04 second, .01 of which the auricles and ventricles are relaxing, and .03 second there is neither a contraction nor relaxation, but absolute rest.

At each contraction of the ventricle there is sent a wave along the entire length of the arteries.

Sounds of the Heart.— If the ear be placed on the chest of another person, over the heart region, two sounds will be heard during each round of the heart's beat. They are known as the first and second sounds of the heart. The first is of a lower tone, but of longer duration; the second,

sharp and quick; they may be imperfectly represented by the syllables "lub," "dub."

The cause of the second sound is the closing of the semilunar valves. As to the cause of the first there is much doubt. Some suppose it to be due to the vibration of the tense ventricular walls during a systole, while the more recent view is that it is double in its origin, partly due to the closure of the semilunar valves.

These sounds are of importance to the physician, as in disease of the heart they are cloaked by other sounds or so modified as to become of great aid in determining the difficulty.

In health, in the adult, the pulse ranges from sixty-five to seventy-five; in children it is faster; in old age, slower, and faster again in extreme age.

A soft pulse, i. e., when the arteries are readily compressible, shows that the heart is not keeping them properly filled; a tense, or hard, pulse indicates that the heart is keeping the arteries excessively full, and is working violently.

How the Valves Adapt Themselves to Variation in Size of Auriculo-Ventricular Openings.— The little muscular pillars projecting from the walls of the ventricles, from which pass tendinous cords, in turn attached to the auriculo-ventricular valves, have a very important function. When these valves close back after the systole of the auricle, they are prevented from swinging too far back by these little tendinous cords; but when the ventricles contract, these little cords become slackened, and the valves would be forced up into the auricles were it not for the contraction of these little papillary muscles, which shorten as the ventricles continue in their contraction, and thus keep the chordæ stretched, and keep the valves from being forced back.

Rate of Flow.— The velocity of the blood differs very much in different parts of its course. It leaves the arteries, going from the heart with a bound, and becomes slower and slower as it reaches the smaller arteries, and at the capillaries the movement is almost imperceptible to the unaided

eye. As the blood leaves the capillaries, the stream becomes quicker in its flow, the greatest velocity of the venous flow being reached in the larger veins. The cause of this difference in velocity in the different parts of the circulation, aside from the force given by the heart impulse, is purely physical. The repeated branching of the arteries increases the surface over which the blood flows, and the greater resistance offered

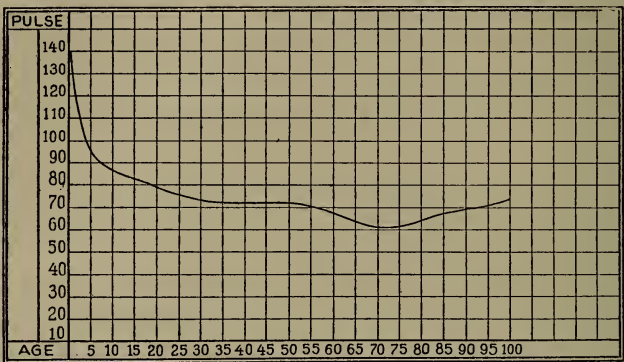


FIG. 136.—PULSE CURVE.
Numbers at left show pulse; those at the base, age.

by this increased surface checks the velocity of the flow; in the vein the converse is true, the capillaries and smaller veins forming larger veins, the surface over which the blood flows becomes less, and a corresponding decrease of resistance follows, and also an increased velocity of the flow.

Work Done by the Heart.— The heart, forcing as it does the blood into the arteries against great pressure, has to do a great work. It is estimated that the ventricles do daily as much work as would be required to lift 193 tons one foot high.

Why Is There No Pulse in the Capillaries?— The loss of the pulse in the capillaries is due to the following facts:—

1. That from their small size they present considerable resistance to the flow due to friction.
2. To the elasticity of the arteries.
3. By their great number the shock becomes divided.

Importance of No Pulse in the Capillaries. — In the capillaries the interchange between the tissues and the blood must take place. If the flow was unsteady or rapid, this could not well take place, but the slow, steady stream through these tiny vessels gives ample time for the interchange.

Taking Cold.— When the skin is chilled, its arteries contract; this throws an undue amount of blood into the internal organs, and they thus become gorged with blood (*congested*), and this congestion very easily passes into inflammation. A continued chilling may pass into a continued inflammation, or cold. Diarrhea is more frequently due to chill resulting in inflammation of the mucous membrane of the intestine than to the fruits eaten to which we usually give blame.

Need of the Blood.—It is not sufficient for the purpose of nutrition that the food products enter the blood. It must be taken to the various tissues whose cells take the food, and make it a part of themselves.

Small animals, like the one-celled forms found in our ponds, the hydra and fresh-water sponge, have no need of blood, as they are so simple that the cell or cells which make up the animal may absorb food from the medium in which they are found; but when they become so complex as to have organs, the labor of the cells is divided: some are concerned in respiration, some in production of motion, some with sensation, and some in preparation of food. Thus many are far removed from the alimentary canal in which the food products are made, and some food must be brought to them so that they may be nourished, and be supplied with materials needed for the performance of their various functions. This is accomplished by the blood and circulatory system. Thus it is that the food products prepared by the alimentary canal are taken to the brain, muscles, bones, and other parts of the body. But this is not the only need of blood. The cells need oxygen. This the blood gets from the lungs. This also must be

taken to the cells. The cells in their activities in the production of heat and motion make waste products which are of use no longer to the system, but must be thrown off, so that we shall have need of currents to and from the cells, and an engine to keep up the currents. This is accomplished by the veins, capillaries, and arteries, and by the heart as a force pump. The blood is thus the medium of exchange between the receiving organs on the one hand (as

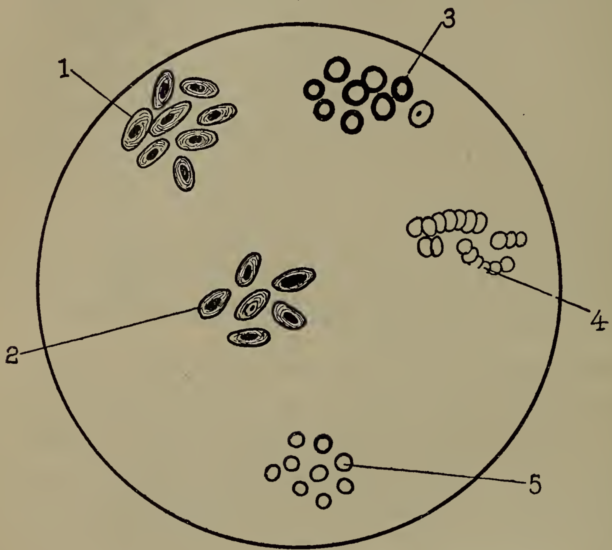


FIG. 137.

1. Red corpuscles of blood of a duck. 2. Red corpuscles of blood of snake. 3. Red corpuscles, blood of rat. 4. Red corpuscles, blood of cat, forming bundles (rouleaus) like rolls of coin. 5. Red corpuscles from human blood. Notice nucleus in 1 and 2, and its absence in 3, 4, and 5. (Brinckley, C. W. B.)

the lungs and alimentary canal) and the excretory on the other.

Where Found.— The blood is found in all parts of the body with the exception of the epidermis, or outer skin, the hair and the nails, most cartilage, and hard parts of the teeth.

Color.—The color of the blood differs in different parts of the body; as it goes to the lungs, it is almost a purple in color; as it returns, it is almost a scarlet in hue; and after

digestion, its color is changed by the absorption of food materials.

Histology.— The blood consists of the plasma and corpuscles. The corpuscles are so small and so numerous that over 50,000 are contained in a single drop of blood. The red are by far the greater in number. The ratio is about one white to three hundred red ones. The plasma is the fluid portion of the blood in which the corpuscles float. It is almost colorless and quite transparent.

The composition of plasma may be learned by the examination of blood serum, which is plasma minus fibrin. While it has the consistency of water, it is not like water in composition. When boiled, it sets like jelly or the white of an egg. This would indicate that it is probably like it in composition, which is true, there being about eight and one-half pounds of albuminous substance to one hundred pounds of blood. It also contains considerable quantities of oily and fatty matters, a little sugar, common salt, carbonate of soda, and small quantities of various other substances, chiefly waste products from the various tissues. It is nine-tenths water.

Red Corpuscles (Fig. 137).—When seen separately, they are of a pale yellow color, but together they are red, and to their color is due the red appearance of the blood. Soon after the blood is drawn, the most of the red corpuscles cohere side by side, in rows resembling piles of coins. The red corpuscles of mammalia resemble those of man, being circular, biconcave, pale, yellow disks. The blood corpuscles of the dog are so much like those of man that they might be mistaken for those of human blood. In most cases their size is sufficient to enable us to distinguish them. The oval shape, and the presence of a nucleus in the red corpuscles of birds, reptiles, amphibians and fishes, will prevent them from being confounded with those of human blood. Each corpuscle is soft and jelly-like. It is composed of water, phosphorus, iron, potassium, and hæmoglobin. Water is the chief constituent, being more than half the weight.

The hæmoglobin has power of uniting with oxygen when that gas is in excess, and of giving it off again when the oxygen is small in amount. In the lungs the hæmoglobin takes up oxygen. To carry oxygen from the lungs to the various tissues of the body is one function of the red corpuscles. The hæmoglobin is dark-purplish red, but when combined with oxygen, it is bright-scarlet red. The bright-red blood is called arterial, and the dark venous.

White Corpuscles. — The white blood corpuscles in the human body are larger than the red. They contain no coloring matter. Each has a well-marked nucleus, and the power to change its own shape. Their movements are so much like those of the amœba that they are called amœboid. The pus, or matter, of a sore is chiefly made up of white corpuscles which have worked their way through the walls of the capillaries.

The Blood Gases. — Ordinary fresh water has considerable air dissolved in it; this is the source from which the fish and aquatic animals derive their oxygen. Blood also contains gases[1] dissolved in it. By exposing the blood to a vacuum, it gives off about sixty pints of gas to one hundred pints of blood. Arterial blood contains more oxygen and less carbon dioxide than venous blood; but, in both, the proportion of carbon dioxide is greater than that of the oxygen, and is the most abundant gas of the blood.

The Quantity of Blood. — The total weight of the blood is about one twelfth or one thirteenth of the weight of the whole body, making for a man of average size about twenty pounds of blood, or somewhat over a gallon and a half.

The Specific Gravity of Blood. — Bulk for bulk, blood is heavier than water, one hundred teaspoonfuls of blood weighing as much as one hundred and five teaspoonfuls of water. The blood is much thicker than pure water. Its specific gravity varies from 1.055 to 1.06, when taken at 15° C. In addition to the solid bodies which float in the plasma it holds a

[1] The percentage composition of arterial blood is: O, 19.2; CO_2, 39.5; N, 2.7: for venous blood, O, 11.9; CO_2, 45.3; N, 2.7.

number of substances in solution,— things which are of great importance, for they are the foods which the blood is carrying to, and the waste which it is carrying from, the various tissues of the body.

The Coagulation of Blood.— When first drawn, blood flows as freely as water. This condition is only temporary. In a few minutes the blood becomes viscid and sticky, resembling thick, red syrup; the viscidity becomes more and more marked until, after the lapse of five or six minutes, the whole mass sets like jelly, adhering to the sides of the vessel so firmly that it may be inverted without being spilled. *Gelatinization* is the name given to this stage of coagulation. This condition, however, is not permanent. In a few minutes the top of the jelly-like mass begins to hollow out, or cup, in the hollow of which appears a small quantity of a nearly colorless liquid, the blood serum. The jelly mass at length shrinks so as to pull itself loose from the sides and bottom of the vessel, and as it shrinks, it squeezes out more and more serum. At last we get a solid clot, red in color, smaller in size than the vessel in which it is contained, but retaining its form and floating in a quantity of pale yellow serum. This series of changes is known as coagulation, or clotting of the blood.

Cause of Coagulation.— When a drop of fresh drawn blood is watched with a powerful microscope, it will be seen to separate into very fine solid threads which run in various directions through the plasma, and form a close network entangling the corpuscles. These threads are composed of an albuminous substance called fibrin. When they first form, the whole drop is much like a sponge soaked full of water (represented by the serum), and having solid bodies (the corpuscles) in its cavities.

After their formation, these threads begin to shorten, causing the fibrinous network to shrink in every direction, and this shrinking increases, the longer the clotted blood is kept. The same thing takes place in the coagulation of the blood in quantity. At first they stick too firmly to the sides

and bottom of the vessel to be pulled away, hence the first sign of contraction is seen in the cupping of the surface after the stage of gelatinization, and this contraction presses out from its meshes the first drops of serum. At last the contraction of the fibrin overcomes the adhesion to the vessel, and pulls itself loose from all sides, and it continues to contract, pressing out more and more serum. Nearly all the red corpuscles are held back in the meshes of the fibrin. The coagulation is produced by an unformed ferment called *thrombin,* which is not present in the blood of the healthy blood vessels, but is formed when the blood is shed. It is supposed that the thrombin is produced by the breaking down of the white corpuscles, especially the polynuclear. The soluble calcium salts of the blood seem to be very important factors in producing coagulation.

Uses of Coagulation.—1. To clog up wounds in the small blood vessels, and thus to stop bleeding. 2. To seal permanently a ligatured blood vessel.

Query. — How are such tissues of the body, as the cartilage, the epidermis, hair, and nails, and the hard parts of the teeth, nourished, since they are not provided with blood vessels?

THE LYMPHATIC SYSTEM.

Part of the plasma of the blood exudes through the thin walls of the blood capillaries, thus coming in contact with surrounding tissues. This exuded plasma becomes the lymph, and contains in solution nutrient material and oxygen set free from the red corpuscles of the blood, and thus becomes a nutritive and respiratory agent for the cells of the tissue, each tissue taking from the lymph what it needs for its life and activity. The surplus lymph, together with the waste products resulting from the metabolism of the tissue, is carried away from the tissues and back to the blood stream by a system of vessels called the *lymphatics.* These vessels have their origin in the tissues, and are found in nearly all parts of the body.

They are, however, most intimately connected with the connective tissue. The lymphatics include the following classes of vessels: (1) lymphatics proper and the gland which belongs to them; (2) the lacteals, which arise from the intestines, and which differ from the lymphatics proper only in their power to absorb chyle during digestion as well as exuded lymph; (3) the serous membranes which inclose cavities, which are in reality large lymph spaces, as the pleural cavity, synovial membrane, peritoneum, and pericardium.

The lymph bathes the tissues, filling up the spaces between the cells and other tissue elements of the body. Including that found in the tissues and contained in the lymph vessels, its quantity exceeds that of the blood-vascular system, and forms more than one fourth of the weight of the body. Bathing the tissues as it does, and being between them and the blood vessels, it acts as a medium of exchange between the blood and the tissues. By the lymph the tissues receive their oxygen and nutrient materials, and into the lymph the tissues receive their waste products.

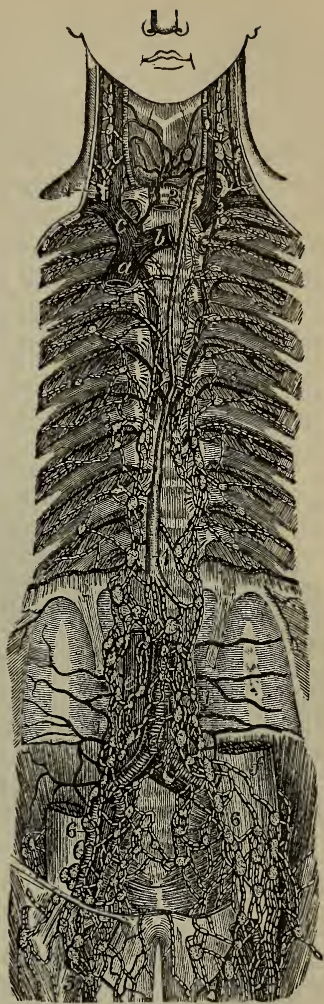


FIG. 138. — VIEW OF THE GREAT LYMPHATIC TRUNKS.

1, 2. Thoracic duct. 4. Right lymphatic duct. 5. Lymphatics of the thigh. 6. Iliac lymphatics. 7. Lumbar lymphatics. 8. Intercostal lymphatics. *a.* Superior vena cava. *b.* Left innominate vein. *c.* Right innominate vein. *d.* Aorta. *e.* Inferior vena cava. 3. Left subclavian vein.

Origin and Structure of the Lymphatics.— The lymphatics begins in most cases as minute channels in the tissues, which unite and form tubes resembling the blood capillaries, but as a rule the lymph capillaries are larger; these soon take upon themselves covering, and resemble the veins, but have thinner walls, a larger proportion of muscle fibers in the middle coat, and much more numerous valves, giving to them a beaded appearance. These collect into larger trunks, forming two main trunks, the larger one on the left side, known as the *left lymphatic duct,* or thoracic duct, and emptying into the left subclavian vein. The lymph is collected by these vessels, and carried to the subclavian veins. There is thus a constant stream of lymph going from the tissues to the lymphatic ducts, and by them to the respective subclavian veins.

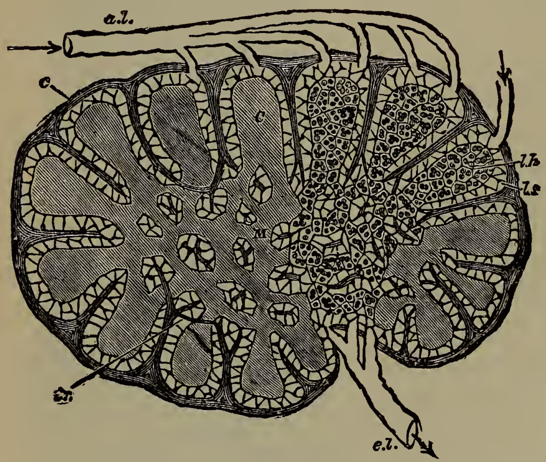


FIG. 139.—DIAGRAMMATIC SECTION OF LYMPHATIC GLAND. *a. l.* Lymph vessels going to (afferent) gland. *e. l.* Lymph vessels going from (efferent) gland. *C.* Cortical substance. *M.* Reticular cords of medulla. *l. s.* Lymph sinus. *c.* Capsule with trabeculæ, *tr.* (Sharpey.)

Some of the lymphatics seem to arise by a plexus, or network of tubes, as in membranes, but many of these vessels commence in irregular (*lacunar*) spaces in connective tissue, (sometimes called lymph spaces), these forming into lymph capillaries. The lymph capillaries form a network in various organs of the body. Their walls are composed of a single layer, endothelial cells. The capillaries form numerous anastomosing branches. In the course of the lymphatic vein there are numerous bodies called lymphatic glands.

In the intestines, lymphatics (here called lacteals) begin by blind extremities in the villi (Fig. 119). In the large serous cavities, the lymphatics, by free stomata on the walls of the cavities, are not, as once supposed, closed cavities, but have numerous openings by the stomata, and by the lymph lacunæ; their fluids are drained away into the lymph capillaries lying in the subserous tissue. In the central nervous system the capillaries have around them for a short distance a lymph capillary in the form of a tubular sheath, so that the lymph that leaves the blood capillary at once enters this tubular sheath, and from this it is carried into the regular lymphatic canals.

It will be seen from what has been given that as the lymph comes in direct contact with the tissues, it reaches parts of tissues which have no blood vessels, such as the epithelium of the mucous membrane, the interior cartilage of the cornua, and the innermost cells and substances of bone.

Lymphatic Glands.— These (Fig. 139.) are small, compact bodies, which occur in the course of the lymphatic vessels. They vary in size from a hemp seed to a kidney bean, and through them pass the lymph and chyle on the way to the blood. They are very numerous in the mesentery, on the sides of the great vessels of the abdomen, thorax, and neck. They are also found in the axilla and groin. They are generally of a flattened oval form, with a depression at one side, called the *hilum,* at which the blood vessels enter and leave the gland, and where also is the exit for the efferent lymphatic vessels. The efferent vessels enter at various points of the periphery.

The lymphatic gland consists (1) of a fibrous envelope or capsule made up of a connective and muscular tissue, from which there passes inward a framework of partitions (*trabeculæ*) which divides the gland into spaces (*alveoli*) with free communications having the form of converging chambers in the cortex, but which become less in size and regularity of shape in the medulla; (2) of the glandular substance proper, which consists of a mass of lymphoid tissue (a fine network of fibers with lymph corpuscles in the meshes),

occupying the central portions of the spaces, and thus leaving a narrow channel bridged across by cells and fibers between the lymphoid tissue and the trabeculæ; (3) a free supply of blood vessels, the arterial branch running in the trabecular framework and breaking in part in capillary networks in the glandular substance; (4) vessels bringing lymph to the gland (*afferent*), and vessels carrying it away (*efferent*).

In the small portion of the tissue crowded with leucocytes, active cell multiplication by indirect (*karyokinetic*) division takes place, so it would seem that one function of the gland is to produce leucocytes that become the white corpuscles of the blood. There are other localities which contain adenoid tissue, as the tonsils, the solitary glands, and Peyer's patches, the spleen, etc.

The lymph which leaves the gland differs from that which enters it, in that it is more coagulable, has been freed of accidental matter, and is richer in leucocytes.

The Thoracic Duct.—This (Fig. 138) is the common trunk which receives the lymph from the lower limbs, from the abdominal viscera, except the upper portion of the liver, from the walls of the abdomen, from the left lung, the left side of the heart, left side of the thorax, the left arm, the left side of the neck, and head.

It is from fifteen to eighteen inches long, nearly one-third of an inch in diameter, but at its lower portion there is an elongated dilation (*receptaculum chyli*). It extends from opposite the second lumbar vertebra to the base of the neck. It passes upward along the front of the body of the vertebræ by a tortuous course, dilating and contracting at irregular intervals, and making a sharp turn, enters the subclavian vein near its juncture with the external jugular vein, having its entrance into the vein guarded by a valve of two segments which permits the contents to pass into the vein, but prevents any reflux. The valves of the thoracic duct are more numerous in its upper portion. The walls of the duct consist of three coats: (1) a lining of flattened epithelial cells, resting upon longitudinal fibers; (2) a

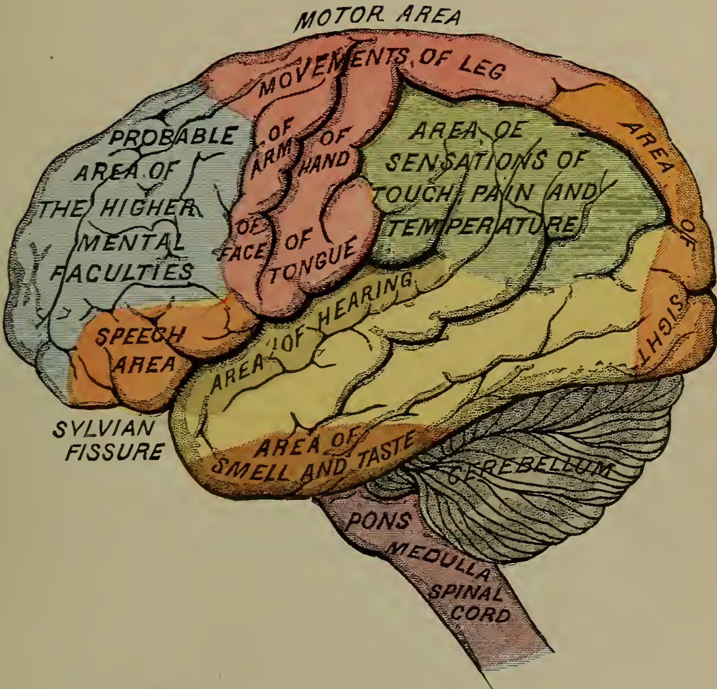


PLATE XII.

FIG. 78.—A DIAGRAM TO ILLUSTRATE THE PROBABLE FUNCTIONS OF VARIOUS AREAS OF THE CEREBRAL CORTEX.
(From Ranney.)

middle coat of connective tissue, above which there are muscular fibers, both longitudinal and transverse; (3) an external coat of alveolar tissue with isolated bundles of muscular fibers.

Conditions Affecting the Amount of the Lymph and Chyle. — Various causes may combine to determine the amount of lymph in the lymphatic spaces and vessels: (1) gravity, as is shown by the swollen limbs and tense skin when standing for a long time or by letting the arms hang at the side and noticing the swollen vessels; while the swelling is partly due to the blood capillaries and veins, the greater part is due to the unusual fullness of the lymph spaces; (2) to pressure, as shown by bandaging the arm, the parts below the bandage becoming swollen by the lymph held back by the pressure of the bandage; (3) muscular exercise, the exercise not only increasing the formation of the lymph, but also promoting its more rapid outflow; (4) increase of blood pressure in the capillaries, due either to capillary dilation or an increased venous resistance or a stronger or more rapid heart stroke; (5) the condition of the living cells of the capillary walls which may prevent the lymph exudation, as in case of conditions given in 4; (6) digestion of a full meal; the amount of chyle greatly increases, the lacteals becoming white and distended though collapsed, and containing only a small amount of clear lymph during the interval between times of digestion; (7) abnormal conditions of the vascular system, as lack of tone of capillary walls, may produce an excessive transudation of the lymph, with an undue accumulation of lymph in the lymph spaces, producing a lymph congestion called edema, or dropsy.

Inflammation. — When part of the tissue of an organ is irritated, it leads to an increased flow of blood, as shown by rubbing the skin briskly. In such a case the blood vessels become dilated and congested, the white corpuscles cling to the sides, and begin to pass through the walls of the blood vessels into the lymph space. When the irritation is great, a morbid condition known as inflammation is produced, characterized by heat, swelling, and redness, with marked vas-

cular changes and much exudation of plasma and corpuscles into the injured tissue.[1] When the inflammation subsides, the white corpuscles cease to emigrate to the blood, the stream quickens, and the normal circulation is again set up; the migrated corpuscles and surplus lymph pass away eventually into the lymphatic channels. If the inflammation, however, continues, a complete arrest of the blood flow may take place; some red as well as some white corpuscles may pass into the tissue, and the accumulated leucocytes degenerate into pus cells, and form an abscess which must be opened, if it should fail to do so naturally.

THE LYMPH.

Normal lymph is a clear, transparent, yellowish fluid of a specific gravity of from 1.012 to 1.022. It is odorless, slightly alkaline, and has a saline taste. Colorless corpuscles resembling those of the blood are found in the lymph. Before passing through the lymphatic glands, the lymph is only slightly coagulable, but after passing through them, and as it advances on its course toward the thoracic duct, the number of corpuscles increases, and the lymph becomes easily coagulated.

Cause of Circulation of the Lymph.— The more important causes of movements of the lymph are: (1) The pressure derived from the blood pressure in the tissue, and by the manner of entering the two lymphatic trunks there is little or no pressure when they enter the blood vessels. This difference of pressure produces an outward flow from the tissues to the openings of the lymphatic ducts into the blood vessels; (2) by the arrangement of valves, every pressure on the ves-

1 If the irritation is caused by the lesion of tissue or the presence of foreign bodies, as bacteria or other micro-organisms, there is set up an active emigration of the leucocytes to the injured part, and these devitalize or engulf and digest the disintegrated tissue or foreign particles, and thus prepare the way for repair of the tissue. The corpuscles which combat the irritating agent are called *phagocytes*. If the phagocytes are strong or numerous enough to devour and remove the irritating substances, they disappear by being carried off into the lymph stream; but if the invading substance is too powerful, the corpuscles themselves are destroyed, and collected in the tissue and pus cells. The destruction of the injurious agent is supposed to be a chemical one, the source of the destructive agents, the invading or irritating influence, being produced by the chemical activity of the cells.

sels by the skeletal muscles in contraction tends to force the lymph onward, and the valves prevent its backward flow; (3) the respiratory movements by every inspiration diminish the pressure in the vessels within the chest; (4) probably the muscular fibers in the lymphatics undergo a rhythmic contraction; (5) the lymph (chyle) of the lacteals is forced onward by the intestinal movements and the contraction of the muscular fibers of the villi; (6) by the union of the lymph vessels into larger trunks, but whose sectional area is less than that of the total area of the tubes forming the trunk. There is thus a constant stream of lymph from the tissues to the two subclavian veins, and thus to the blood.

Uses of the Lymph.—The uses of the lymph are many, the more important of which may be mentioned: (1) It bathes the tissues, and acts as a medium of exchange between the cells and the cell elements of the tissue and the blood. The method by which this exchange is made is something more than simple osmosis. In addition to the process of osmosis there is probably filtration, the lymph passing through the tissue under pressure. It also is greatly influenced by the activity of the endothelial cells of the capillary wall. The fact that one half of the indiffusible proteids of blood plasma pass into lymph shows that it is something more than osmosis; that it is not due to filtration alone is shown by the fact that increased pressure is not always followed by increased lymph exudation, and also by the fact that waste products often pass from the lymph spaces to the blood. When peptone is injected into the blood circulation of a living animal, there is produced an increased flow of thicker lymph, a more concentrated plasma passing through capillary walls, the peptone also passing and disappearing in the lymph. This would seem to imply an active process of secretion by the cells of the capillary wall; (2) to remove waste products that have been formed by the activity of tissue, which may not reach the blood by osmosis; (3) as a circulating medium between the tissues and the blood; (4) as absorbent vessels gathering matter and passing it to the blood.

CHAPTER X.

RESPIRATION.

EXPERIMENTS AND DEMONSTRATIONS.

I. To determine the structure of the lung: Obtain from the butcher a calf's or a hog's lung. It is best to get one with the heart attached, as in removing the heart, holes are likely to be cut which will interfere with the inflating of the lungs. In dissecting note carefully: —

1. Shape and size of the larynx, and position of the glottis and epiglottis.

2. Relation, shape, size, and structure of the trachea.

3. Color, size, shape, specific gravity, and relation of the lungs to the heart, etc.

4. Trace out the larger blood vessels connected with the lungs and heart.

5. Carefully slit open the trachea on its posterior; carefully examine its inner surface. Do you find any glands? Determine the structure and shape, form and number of the rings. Do you note any difference in their size? Trace the rings to the bronchi.

6. Carefully trace out the division of the bronchus as far as you can.

7. Carefully cut off the left lung at the beginning of the left bronchus.

II. Tie into the left bronchus a few inches of glass tubing of convenient size; tie very firmly. On the end of the tube, tie a few inches of rubber tubing. On blowing into the tube, the lung will be distended, and as soon as the opening is left free it will collapse. What does this show of the structure of the lungs?

Now carefully inflate the lung as completely as possible, and while inflated; firmly tie the rubber tube, about two inches from the glass tube, so that the air cannot escape.

Take a U-shaped tube one-fourth inch in diameter, and with arms eighteen inches long. Pour mercury into the tube until it stands about four inches in each arm. Tie the free end of the rubber tube connected with the inflated lung to one arm of the U-shaped tube. Cut the string that confines the air in the lung, and gradually admit the air into the tube. Does the mercury rise in the opposite arm? Why? How much? Find the difference in level. Try the same experiment with an inflated rubber balloon.

III. Dissect out and identify the muscles mentioned below.

1. Carefully determine the structure and relations of the diaphragm.

2. Dissect out the serratus, and determine its action as an inspiratory muscle. Do the same for the pectoralis major and minor and scaleni.

IV. To show that elasticity of the lung aids in expiration, make a piece of apparatus as follows: Into the lid of the ordinary self-sealer glass fruit jar have soldered two tin tubes about one-fourth inch in diameter; one near the center and the other near the edge. Let the one near the edge project below the surface of the top two inches, and above one and a half inches; to the one in the center tie a rubber balloon so that it can be inflated by blowing into the tube above. To the outer one connect a rubber tube of sufficient length and size, and then connect with an air pump. Now exhaust the air from the jar, and notice any change that may take place in the balloon. Give reason for the change. Admit the air to the jar. Explain what takes place. In what way does this resemble the manner in which we breathe?

Queries.— 1. Why is it that as soon as the air is admitted to the pleural cavity the lungs collapse?

2. What difference would be made in our mode of breathing if the lungs were not elastic?

3. By what force are the lungs stretched? What principle of physics is involved? Give reason for your answer.

4. Why does the expansion of the lungs keep up with that of the chest wall? Is there a vacuum or partial vacuum

produced as in the jar apparatus? Give reason for your answer.

5. What muscles should be brought into action to produce artificial respiration? Determine by careful examination of the muscles of a cat.

EXPERIMENTS.

1. To Determine Force of Expiration: Make a U-shaped one-fourth-inch glass tube having even arms about eighteen inches in length and two inches apart. Support the tube so it can stand vertical. Into one arm pour mercury (quicksilver) until it stands on a level in both arms, about four inches high; to one arm attach a piece of rubber tubing. Into the free end of the rubber tubing insert a piece of glass tubing two or three inches long, leaving about an inch and a half out of the tube. Now blow through the tube, and see to what height you can raise the mercury in the opposite arm. Let a number of persons try the experiment. Compute the weight of the mercury you lift. Try the force of suction by taking a deep, forced inspiration. What effect upon the relative heights of the columns? Why is the result opposite that of the first experiment? What important principle does it teach? Compute the difference between the expiratory and inspiratory efforts. Determine the average inspiratory and expiratory efforts.

2. To Determine the Vital Capacity: Take a larger bell-jar, and fill it full of water; now invert it into a pneumatic trough partly filled with water so that when the water is forced out of the jar the water in the trough will not overflow. Support the bell-jar by a string and pulley and weight so that it will be balanced.

Take a piece of rubber tubing about a yard long. In one end of the tubing insert a piece of glass tubing about four inches long, so that about two inches will remain out of the tube. Place the end with the glass tube in the mouth and the other end of the tube under the bell-jar, so that it will reach up some distance in the jar. Without taking more than an ordinary inspiration, force the water out of the jar by an ordinary expiration. Mark the distance to which the water falls. Take as deep an inspiration as possible, and after filling the jar with water expel it as much as possible by as great an expiratory effort as you can make.

Again mark the point to which the water falls. Now without removing the tube from the mouth, make an inspiration. Does the water rise in the jar? Why? Let a number of persons try the experiment, and note carefully in each case the fall of the water. After the first experiment remove the jar from the water, and determine the amount of water (in quarts) required to fill it up to the first mark. Then round the edges of the glass tubing, so that by holding the end in the Bunsen or alcohol flame they will not cut the mouth.

3. Take a glass or beaker full of lime water.[1] By means of a piece of glass tubing, eight or ten inches long, breathe into the lime water, and continue breathing until a white precipitate is formed. What is the cause of the precipitate?

Place several small pieces of marble in a small flask or a large test-tube with a cork having a delivery tube. Add some dilute acid, and quickly cork and place the end of the delivery tube into a beaker or glass of lime water. Do you get a precipitate? Is it like the one you got in the first part of the experiment? Marble is a carbonate of lime, and when an acid is added to it, carbon dioxide is given off, which, joining with the lime water, makes calcium carbonate, which is insoluble. Where did the carbon dioxide of the breath come from? What have we learned is one of the chief waste products in muscular contractions?

4. Turn down a Bunsen burner until there is only a small flame, and place over it a four-inch or five-inch funnel having a delivery tube running from the small part of the funnel into a glass of lime water. Is a precipitate formed? What is formed by the burning of the gas? If the carbon of the gas joins with the oxygen of the air, what will be formed? What use do the tissues make of the oxygen?

5. Place on a wooden float a piece of candle. Light the candle, and place in a pneumatic trough or bucket of water. Cover with a bell-jar or a large fruit jar. Why does the candle go out? Leaving the mouth of the jar closed by the water, remove the float. Close the mouth of the glass jar with a glass square or piece of wood; invert the jar quickly,

[1] Lime water may be made by adding unslacked lime to pure water until it will no longer dissolve. Set the solution aside for a few hours, and then filter, saving the clear water that passes through the filter. Keep in well-corked bottles.

and remove the jar from the pneumatic trough. Remove the cover, and put in 10 or 20 c.c. of lime water; put on the cover, and shake the jar to secure the mixing of the gas and lime water. Does the lime water become milky, or is there a precipitate formed? What does this indicate?

Repeat the experiment, but admit air by means of two bent glass tubes or by two rubber tubes. Does the candle continue to burn? Why? Test as before with lime water. Do you get so marked a test for carbon dioxide as in the first case? What do you learn in this experiment of the effect of carbon dioxide upon combustion? Why do we use two tubes?

If the chemical changes which take place in the cells are oxidations, would carbon dioxide, if not removed by the tissue, tend to prevent this oxidation? Why do the tissues need oxygen?

In a closed room how does respiration of the persons in the room render the air unfit for rebreathing? How may the injurious effects be prevented?

6. If 1,200 cubic inches of air is rendered unfit for breathing by one person in breathing one minute, what volume of air will be required to last 100 persons one hour?

7. A schoolroom is 30 feet by 60 feet by 12 feet; how long will this amount of air last 30 pupils if 1,200 cubic inches is required per minute for each pupil? How much air must be supplied each minute to keep the air fit for breathing?

8. By what has been given, test the air supply of your sleeping room.

THE RESPIRATION. — TEXT.

Need.— As a result of the activity of the cells of the various tissues of the body, there is produced, directly or indirectly, through a series of decompositions, carbon dioxide. This is the most abundant of the waste products. While it is a normal product of the cells' work, its presence in any large amount in the blood or in the tissues is injurious to the activity and health of the tissue. It must be removed from the tissue by the blood, and then from the blood before it returns to the tissue.

Many of the chemical processes which take place in the

cell are dependent upon a gas which is plentiful in the air; i. e., oxygen. There are also a number of products from digestion which have been absorbed by the blood, whose energy cannot be set free without the aid of oxygen. There is constant demand for this material, and therefore a constant supply must be kept up.

Respiration has for its objects (1) to renew the supply of oxygen in the blood, and (2) to get rid of the carbon dioxide.

As this work is so different from any we have considered, and as we have learned that new functions require new organs or modification of organs, we shall expect to find a separate set of organs to perform this work. Not only do we find this, but when we extend our observations to the lower animals, we learn this very important truth. The more extended the work of oxidation is to be, the more complex and better developed is the respiratory apparatus, and the more thoroughly the blood is aërated; i. e., charged with oxygen.

Respiratory Apparatus.— The respiratory tract consists of the air passages and the lungs. These consist of the nose opening into the pharynx by the posterior nares; of the mouth opening into the same cavity by the fauces; of the pharynx opening on its ventral side by a slit (the *glottis*) into the larynx; of the larynx opening below into the trachea; of the trachea, which divides into two great branches, or bronchi; of the bronchi, which divide into a large number of smaller tubes, and these finally after many subdivisions open into subdivided elastic sacs with pouched walls.

We shall not at this time describe the nose, nasal fossæ, larynx; the pharynx was described when we considered alimentation; the others will be described when we consider the voice and the sense of smell, respectively.

We should, however, in this connection, note the position of the larynx (Fig. 140*a*), surmounting the trachea, and in front of the pharynx; that it is a triangular box made up of nine cartilages, three single and three pairs, bound to-

gether by ligaments, and moved by numerous muscles; and that the interior is lined by mucous membrane, is supplied with blood vessels and nerves, and contains the vocal cords.

The Trachea.—The trachea (Fig. 140*a*) extends from the larynx to the bronchi; its length is about four and a half inches, and its diameter about three fourths of an inch. It is a cylindrical tube lined by mucous membrane, with a supporting stratum of connective tissue and plain muscular tissue. The wall contains from sixteen to twenty cartilages which have the form of imperfect rings, and extend about two-thirds the way round the trachea. The third not supported by the rings rests upon the esophagus.

The bronchi and bronchial tubes are very similar in structure to the trachea; these rings, like those of the trachea, are only partial rings, but are so placed that they give support to the entire circumference of the tube by not having the partial ring with their openings at the same place.

The Cilia of the Air Passages.— The greater portion of the mucous membrane of the nose, the nasal fossa, the pharynx, down to the opening of the posterior nares and that of the trachea and its branches, down to almost the smallest, have a layer of ciliated cells on its surface. Each of these cells has on its free portion, which is turned toward the cavity of the tube, from twenty to thirty slender threads which are in constant motion. These little thread-like bodies are called cilia. This motion serves a very important function which will be described later.

Lungs.—The lungs (Figs. 5 and 140*a*) are suspended in the chest by the root of the lungs, consisting of the pulmonary arteries and veins, bronchial arteries and veins, lymphatics, bronchial tubes, and areolar tissues, all inclosed by reflection of the pleura.

The lung is composed of an external serous (*pleura*) coat, a subserous coat containing a large proportion of elastic fibers, and the parenchyma. The parenchyma is composed of lobules which vary in size; those of the surface are large and of pyramidal form; those of the interior, smaller, and

of various forms. Each lobule is composed of one of the ramifications of the bronchial tube and its terminal air cells, and of the ramifications of the pulmonary and bronchial vessels, lymphatics, and nerves, all of these structures being connected together by areolar fibrous tissue.

The bronchial tubes (Fig. 140) become smaller and smaller by continued division until they are from one fiftieth to one thirtieth of an inch, when they become changed in structure, losing their cylindrical form and continuing onward as irregular passages (air sacs) through the substance of the lobule, their sides and extremities being closely covered by numerous saccular dilatations, the air cells.

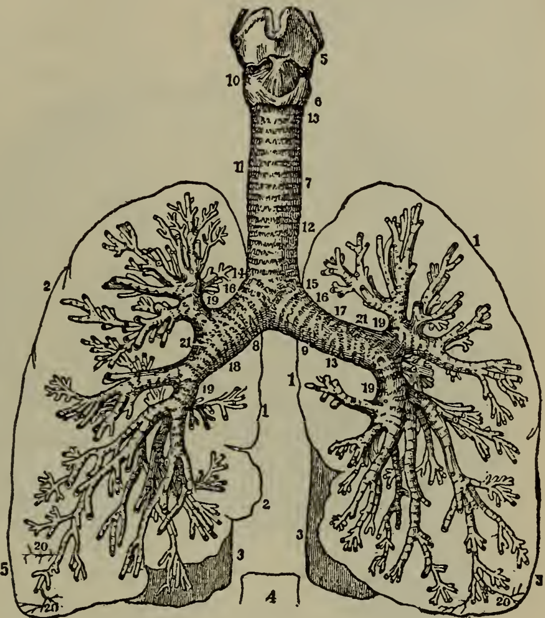


FIG. 140A.—ORGANS OF RESPIRATION.
1. Left lung. 2. Right lung. 5. Larynx. 7. Trachea. 9. Left bronchus. 14, 15, 16. Bronchial tubes.

The Air Cells.— The air cells are small, polyhedral, cup-shaped depressions separated from each other by thin septa, and communicating freely with the intercellular passages, or air sacs. They are best seen in the surface of the lungs; they vary in size from one two hundredth to one seventieth of an inch. The important changes to be noticed in the structure of the air cells are the loss of muscular fibers,

the extreme thinness of the mucous membrane, the abundance of elastic fibers, and the change from columnar ciliated cells to pavement epithelium.

Pulmonary Capillaries.— These are found just beneath the mucous membrane in the walls of the septa of the air cells and the air sacs; their walls are very thin, and they form plexuses having very minute meshes.

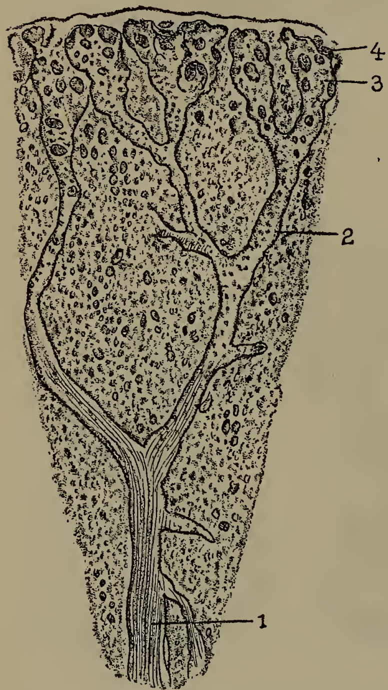


FIG. 140 B.—STRUCTURE OF LUNGS.
1. Bronchial tube. 2. Bronchiole. 3. Infundibulum. 4. Alveolus.

Pleura. —Each lung is invested on its external surface by a very delicate serous membrane (the *pleura*), which incloses the organ as far as its root, and is then reflected upon the inner surface of the thorax. The cavity between these two layers is called the cavity of the pleura. Each pleura is a closed sac, one occupying the right half of the thorax, and the other, the left. The two pleuræ do not meet in the middle of the chest, excepting opposite the upper part of the second piece of the sternum. There is a space (the *mediastinum*) thus left between the two, which contains all the viscera of the thorax except the lungs.

The Diaphragm.—This, it will be remembered, is the muscular membrane which divides the ventral cavity into two parts, the thorax and abdomen. It is made of two muscles (*diaphragm major* and *diaphragm minor*). The first originates by fleshy slips from the lower portion of the sternum (*ensiform appendage*) and from the inner surface of

the cartilage of the last six ribs. Converging by all its fibers to a broad central tendon, it is inserted into a tendon which is notched in shape at the vertebral column, and pointed near the sternum (the *cordiform tendon*). There is an opening (*foramen quadratum*) near the spine through which the vena cava ascends. The second originates by four pairs of fleshy

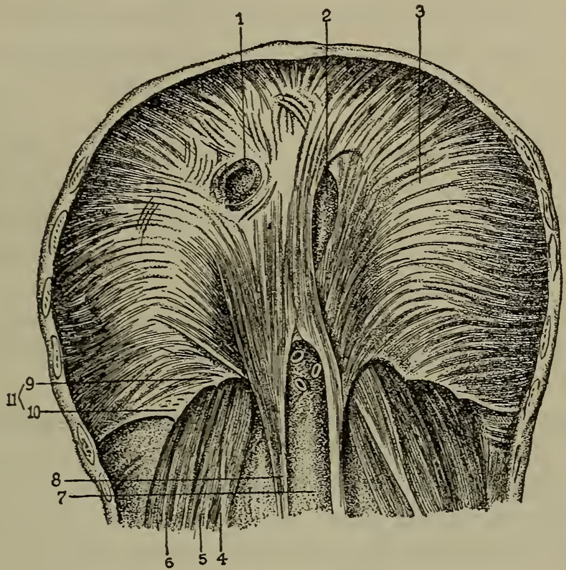


FIG. 141.—THE DIAPHRAGM. INFERIOR SURFACE.

1. Foramen for vena cava. 2. Opening for the esophagus. 3. Central tendon. 4. Psoas minor muscle. 5. Psoas major. 6. Quadratus lumborum. 7. Opening for the aorta and the thorac duct. 8. Right crus. 9. Median arch. 10. Lateral arch. 11. Lateral crus made from 9 and 10.

and tendinous slips, the longest of which arises from the third and fourth lumbar vertebræ; the second from the ligament between the second and third lumbar vertebræ; the third pair from the sides of the second; and the fourth pair from the base of the transverse process of the same vertebræ. It passes by muscular bands upward into two columns, one on each side, and is inserted into the back and notch of the cordiform tendon. In this muscle there are two openings, one (*esophageal*) through which passes the esophagus and

pneumogastric nerve; through the other (*hiatus aorticus*) the aorta, thoracic duct, and the greater splanchnic nerve.

Respiration consists of two acts, *inspiration* and *expiration.* The former is an active effort even in ordinary breathing, while the latter is a passive one. They both, however, become active efforts in forced respiration. When we notice the movements of the chest during normal breathing, it is seen that during inspiration the chest becomes enlarged in its diameter from before backward, the sternum being thrown forward and upward (Fig. 100). The lateral width of the chest is also increased.

In a woman the movement of the upper part of the chest is often conspicuous, the chest rising and falling at every respiration; in a man, however, the movements are almost entirely confined to the lower part of the chest, showing that they are diaphragmic.

In labored respiration all parts of the chest are alternately expanded and contracted, the chest rising and falling as much in a man as in a woman.

Inspiration.— There are two chief means by which the chest is enlarged in normal inspiration,— the descent of the diaphragm and the elevation of the ribs. The former causes that movement of the lower part of the chest and abdomen seen in a man's breathing and called *diaphragmic;* the latter causes the movement of the upper part of the chest seen in women's respiration, and hence is called *costal.* It should be remembered that even in the respiration of a woman the diaphragm takes an important part, while in a man the diaphragm is the chief respiratory agent. The descent of the diaphragm is effected by means of the contraction of its muscular fibers. When at rest, it presents a convex surface to the thorax; when contracted, it becomes much flatter, and in consequence the level of the chest is lowered. In descending, the diaphragm presses on the abdominal viscera, and so causes a projection of the flaccid abdominal walls. The elevation of the ribs, however, is a more complex movement.

Since all the ribs have a downward slanting direction,

they must all tend, when raised toward the horizontal position to thrust the sternum forward; some more than others, according to their slope and length. The elasticity of the sternum and costal cartilages, assisted by the articulation of the sternum to the clavicle above, permits the front surface of the chest to be thus thrust forward as well as upward when the ribs are raised. By this the diameter from before backward is enlarged. The elevation of the ribs increases not only the diameter from before backward, but also from side to side.

The ribs are raised by the contraction of certain muscles. Of these the external intercostal are perhaps the most important, being assisted by the *scaleni.* Next in importance are the *levatores costarum.* Some deny, however, that either set of intercostals takes any important part in raising the ribs. They think the only use of their contraction is to render the intercostal space firm and the whole thoracic cage rigid, so that the thorax is moved as a whole by the other muscles mentioned.

Labored Inspiration.—When respiration becomes labored, other muscles are brought into action, the number of the muscles concerned and the degree of their contraction varying with the demands of respiration. Among the more important may be mentioned the *serratus posticus superior,* elevating the second, third, fourth, and fifth ribs.

In forced respiration the lower false ribs, not very noticeable in easy breathing, come into play. They are depressed, retracted, and fixed by giving increased support to the diaphragm and directing the whole energy of that muscle to the vertical enlargement of the chest. The *serratus posticus inferior,* by depressing and fixing the last four ribs, acts as an aid in respiration. When, however, the need for greater inspiratory effort becomes urgent, all the muscles, which can form any fixed act in enlarging of the chest, come into play. In this way the *serratus magnus* acts on the first eight or nine ribs; the *pectoralis minor* acts on the third, fourth, and fifth ribs, the *pectoralis major* from the second to the

sixth; the *latissimus dorsi* on the last three ribs; all of these serve to elevate the ribs, and thus enlarge the chest. Every muscle, which by its contraction can either elevate the ribs or contribute to the fixed support of muscles which do elevate the ribs, may in great efforts be brought into play.

Expiration.— In normal, easy breathing, expiration is, in the main, simple, the effect of elastic reaction. By the effort of inspiration the elastic tissue of the lungs is put on a stretch. Being thus on a tension, as soon as the muscles of inspiration begin to relax, the elasticity of the lungs comes into play, and drives out a portion of the air contained in them. The elasticity of the sternum and costal cartilages causes them to return to their former position, thus depressing the ribs and lessening the dimensions of the chest. When the diaphragm descends by pushing down the abdominal viscera, it puts the abdominal walls on the stretch, and hence when the diaphragm begins to relax after an inspiration, the abdominal walls return to their place, and by pressing upon the abdominal viscera, push the diaphragm up again to its position of rest. While expiration during easy breathing is principally an elastic reaction, there is probably some, though in most cases, a very slight, muscular action to bring the chest more rapidly to its former condition. This is supposed by many to be effected by the internal intercostal acting as depressor of the ribs. The contraction of the abdominal muscles probably assists in the return of the abdominal wall; also the *triangularis sterni* by pulling down the costal cartilages.

Labored Expiration.— In this act the abdominal muscles become important expiratory agents. By pressing on the contents of the abdomen they thrust them, and therefore the diaphragm also, up toward the chest, the vertical diameter of which is thereby lessened; while by pulling down the sternum and middle and lower ribs they lessen also the cavity of the chest. They are in fact the principal expiratory muscles. They are probably assisted by the *serratus posticus inferior* and portions of the *sarco-lumbalis*. When expira-

tion becomes more and more labored, every muscle in the body, which by contraction either depresses the ribs or presses upon the abdominal viscera or affords support to muscles having this function, is called into play.

How Respiration Takes Place.— The lungs are placed in a state which is always one of distention, varying in degree; as the chest enlarges, they, together with the heart, great blood vessels, and other organs, completely fill the air-tight thorax.

The enlargement of the lungs consists chiefly in an enlargement or expansion of the pulmonary alveoli, the air in which becomes, by expansion, rarefied. This makes the pressure of the air within the lungs less than that outside them, and this difference of pressure causes a rush of air through the air passages into the lungs until an equilibrium is established between the air inside and that outside. This constitutes an inspiration. When, by the relaxation of the inspiratory muscles and elasticity of the lungs and chest walls, aided perhaps to some extent by the contraction of certain muscles, the chest returns to its former size, the pressure within the lungs becomes greater (by the air in the reduced alveolus becoming compressed) than that of the air outside. The air moves out as air flows in from the high to the low pressure. This continues until the pressure within the lungs and that without is in equilibrium. This constitutes an expiration.

The fresh air introduced into the upper part of the pulmonary passages, by inspiration, contains more oxygen than the lower part of the lungs. By diffusion, the new, or tidal, air gives up its oxygen to, and takes carbon dioxide from, the old or stationary air, aud thus when it leaves the chest in expiration, it has been the means of both introducing oxygen into the lungs and removing carbon dioxide. It is in this way, by the ebb and flow of tidal air, and by diffusion between it and the stationary air, that the whole air in the lungs is being constantly renewed.

In ordinary respiration the expansion of the chest never reaches its maximum by mere forcible muscular contraction,

and additional thoracic expansion is produced, causing an inrush of a certain additional quantity of air to restore the equilibrium. This additional quantity over that of ordinary respiration is called *complemental air.*

In forced respiration the cavity of the chest is then reduced, and an additional amount of air forced out; the amount thus forced out, over that of ordinary respiration, is called reserve or *supplemental air.* But even with strongest forced expiration there is still some air in the lungs. This is called *residual air.*

The total amount of air that can be given out by the most forced expiration following the most forcible inspiration, that is, the sum of the complemental, tidal, and supplemental air, is called the *vital capacity.* Although the amount varies largely, yet from 200 to 250 cubic inches would represent the average. Of the whole measure of the vital capacity, about thirty cubic inches is an average of the tidal air, the remainder being nearly equally divided between the complemental and reserved air. The amount left in the lungs after the deepest expiration averages from eighty-four to one hundred and twenty cubic inches.

Changes of the Air in Respiration.— During the stay in the lungs, or rather its stay in the bronchial passages, the tidal air (chiefly by diffusion) effects exchange with the stationary air, and as a result, the expired air differs from inspired air in several particulars.

1. **Temperature.**—The temperature of expired air is variable, but under ordinary circumstances, is higher than that of inspired air. The expired air takes its temperature from that of the body, which is usually higher, but it may at times be lower than that of the atmosphere. The temperature of the inspired air depends (1) on the relative temperature of the blood and the inspired air, and (2) on the depth and rate of breathing. The change of temperature does not take place in the lungs, but in the upper passages and chiefly in the nose and pharynx.

2. **Amount of Water.** — The expired air is loaded with water vapor. The amount of moisture taken up by the expired air depends (1) upon the relative humidity of the inspired air; (2) upon the temperature of the inspired air, the amount increasing with the rise of temperature. The moisture, like the warmth, is imparted not in the lungs, but in the upper air passages. The inspired air is, therefore, as it passes into the bronchi, already saturated with moisture.

3. **Amount of Oxygen.** — The expired air contains about four or five per cent less oxygen, and about four per cent more carbon dioxide than inspired air, the quantity of nitrogen suffering little change. The amount of nitrogen in expired air is sometimes greater than in inspired air; it sometimes equals it, and is sometimes less.

In a single breath the air is richer in carbon dioxide and poorer in oxygen at the end of the breath than at the beginning, hence the longer the breath is held, that is, the greater the pause between inspiration and expiration, the richer the expired air will be in carbon dioxide.

The quantity of oxygen used, and carbon dioxide given off, is subject to very wide variations even in the same individual.

4. **Impurities.** — Besides the carbon dioxide and moisture, the expired air contains various impurities, many of which are of an unknown nature, and in all small quantities traces of ammonia have been found. The water vapor found in the expired air contains organic matter, which, from the micro-organisms introduced in the inspired air, is very likely to putrefy, many products of which are poisonous. The bad odor of the breath is often due to the presence of these products. Air containing one per cent of carbon dioxide from breathing is highly injurious, even if the air should contain only .08 per cent of carbon dioxide from breathing, is unwholesome, not so much from the carbon, as from the accompanying impurities. To keep the percentage of carbon dioxide at one per cent, an average man should be supplied with at least 120,000 liters of air per hour.

Need of Ventilation. — If a person were placed in an air-tight room, it would not be long until he would become poisoned by his own breath. When the per cent of carbon dioxide reaches more than one per cent of the air, the air is unfit for respiration. As 2,000 liters of air are rendered unfit for breathing in one minute, it will not take long to render the air of the room unfit for breathing. The supply of fresh air must equal the amount rendered impure if the air is to be kept fit for breathing. This can only be had by ventilation. When the percentage of carbon dioxide in the air is equal to, or greater than, that of the blood, the blood returns to the heart unchanged and to the tissues unpurified, returns to the heart more heavily laden with carbon dioxide, and finally becomes so impure that the heart ceases to beat under its poisoning influence, and death by asphyxia is the result.

Importance of Deep Breathing. — Lung capacity has been very appropriately called the "vital capacity." Every cell is dependent upon oxygen for its proper activity. The lungs are the source of the supply of this important element. Good lung capacity gives endurance and health to the body.

The lungs, like other organs of the body, need exercise to reach their best development; if this is not given by the employment in which we are engaged it must be supplied by exercises in breathing.

Avoid all positions and modes of dress which interfere with the proper development of the lungs. If you have good lungs, keep them so by frequent deep breathing; if weak lungs, strengthen them by special attention to daily exercises in deep breathing.

Breathe Through the Nose.—This is important: (1) to remove the dust from the air inspired by the action of the cilia of the mucous membrane of the air passages; (2) to bring the air more nearly to the temperature of body, by its passage through the nasal fossæ; (3) to give moisture to the air inspired by its passage over the upper part of the air passage. Very dry air would be irritating to the delicate lining membrane of the lungs.

One of the evil effects from smoking comes from the irritating effect of the dry smoke.

If the air be too cool, it tends to congest the mucous membrane of the lungs, resulting in a cold, inflammation, or pneumonia.

In running we should be very careful to observe this rule, as the increased volume of air inspired increases the danger of congestion to the lungs.

CHAPTER XI.

METABOLISM.

FOODS.

As we have seen, the body is a machine for the transformation of energy. This energy must come from our food, and is needed (1) to produce animal heat; (2) muscular contraction (motion); (3) to carry on the work of the nervous system (sensation and stimuli); (4) for the work of the special senses. If the body is to keep its vigor and power, this energy must be maintained; if it is to increase its power and size, it must have energy in excess of that needed for its present requirements.

How much food is needed? This is a vital question, but its answer involves many difficulties. We do not know the secret process by which the food is transformed into tissue or its energy is set free to produce life, motion, heat, and sensation; and we are equally ignorant of the physical and chemical properties of the substance (protoplasm) by which these changes are produced. How, then, is our question to be answered.

Every engineer has a similar problem to solve. He is to maintain the speed of the train, and keep up the proper heat for the warming of the cars for the comfort of the passengers. The source of the needed energy is in the coal, water, and air. His problem is, How much water, how much coal, how much air are needed to keep up the fire and steam pressure? A like problem presents itself in our great heating plants, and here we see it answered in a scientific way. The weight of the coal used is determined; the amount of water used, measured; the number of heat units produced, estimated; the ashes are weighed, and the loss by smoke computed. Thus by knowing the wastes, the available en-

ergy produced, and the amount of fuel used, the value of given fuel can be determined, and the amount needed to maintain a given temperature in the buildings to be heated. By a similar method we may determine the amount of food and oxygen needed for the body.

By carefully estimating the amount of food and air taken in the body (the *ingesta*), and determining the waste products of the undigested parts of the food, we may learn the nature and quantity of the energy produced and the food value of any article of diet.

The substances taken (*ingesta*) are food and the inhaled oxygen. The waste and cast-off products are urine, fæces, sweat, and expired air, and a small amount by the sebum, cast-off epithelium, hair, etc.

The more important elements of the income and outgo of the body are nitrogen, carbon, and oxygen, and, by estimating these, we may approximate the nature and quantity of the metabolism of the body.

Carbon Equilibrium. — If as much carbon is taken up as is given off, the body is said to be in *carbon equilibrium;* i. e., the amount taken and the amount consumed are equal. If more carbon is taken up than is given off, the body stores up the organic matter; but if the amount given off is greater than that taken, part of the organic substance is being lost.

The proportion between the carbon dioxide exhaled and oxygen inhaled gives us the means of determining how much of the inhaled oxygen is used to oxidize the carbon,[1] and how much is used to oxidize other elements, especially hydrogen. The proportion between the carbon dioxide exhaled and the oxygen inhaled is called the *respiratory quotient.*

Proteids and fats do not contain enough oxygen to oxidize their hydrogen; they will, therefore, need oxygen both for their carbon and part of their hydrogen, so that the amount of carbon dioxide will be less than the oxygen in-

[1] Carbohydrates contain enough oxygen to oxidize all the hydrogen (the proportion of typical carbohydrates being hydrogen 2 and oxygen 1), so that oxygen inspired goes to oxidize the carbon. The oxidized hydrogen will be given off as water (H_2O), and that of the carbon as carbon dioxide (CO_2).

haled. When pure carbon is oxidized, the resulting volume of carbon dioxide is the same as the oxygen consumed, and in such a case the respiratory quotient is said to be *one.*

If the part of the oxygen inhaled is used to oxidize the hydrogen or any other element, the carbon dioxide exhaled will be less than the oxygen inhaled, and the respiratory quotient will be *less than one.*

The respiratory quotient can be greater than *one* when the carbon dioxide exhaled is greater than the oxygen inhaled. This can be the case when, in the body, carbohydrates, which are rich in oxygen, are reduced to products containing less oxygen, as in the formation of fats. From what has been said it will be seen that in the case of oxidation of fats in the body the respiratory quotient will be less than one, as the fats have not enough oxygen to oxidize their carbon and hydrogen. Compare the composition of the fats and carbohydrates in the following table:—

Carbohydrates.		*Fats.*	
Glucose,	$C_6\ H_{12}\ O_6$	Palmitin,	$C_{51}\ H_{98}\ O_6$
Maltose,	$C_{12}\ H_{22}\ O_{11}$	Stearin,	$C_{57}\ H_{110}\ O_6$
Cane Sugar,	$C_{12}\ H_{22}\ O_{11}$	Olein,	$C_{57}\ H_{104}\ O_6$

Notice that the carbohydrates contain enough oxygen to oxidize the hydrogen so that all the inhaled oxygen can be used to oxidize the carbon. How is it in case of the fats, if one oxygen atom is required to oxidize two hydrogen atoms to form one molecule of water (H_2O)?

Nitrogen Equilibrium.— Proteid metabolism may be estimated by determining the amount of nitrogen[1] in the nitrogen wastes (urea, etc.) of the body. If the amount of proteids decomposed in the body is equal to the proteids taken up, the body is said to be in *nitrogen equilibrium.* If more nitrogen is taken up by the body, there is an increase of the

[1] As the proportion of the nitrogen to the carbon in proteids is 1 to 3.3 (by weight), for every gram of nitrogen appearing in the waste products, there will be 3.3 grains of carbon oxidized, and a corresponding amount of carbon dioxide. By estimating the amount of carbon dioxide due to proteid oxidation as shown by the nitrogen consumed, and taking this amount from the total output of carbon dioxide, we may determine how much of the carbon dioxide is due to the oxidation of carbohydrates and fats, and thus determine the nature and quantity of the metabolism taking place.

proteid material, and hence an increase of flesh. If the body gives off more nitrogen than is taken up, there will be a loss of proteid material.

Problems.— 1. From the following data[1] determine the condition of the nitrogen and the carbon equilibrium: —

Income (food and oxygen)	3480 grams containing	321 C, 21 N, 30 Salts.
Outgo (various excretions)	3342 " "	280 C, 21 N, 20 Salts.
Difference,	+ 138	+ 41 C

1. Is carbon stored up?

2. In the present case the volume of the oxygen inhaled was 503 liters and the carbon dioxide exhaled 464 liters. From the formula, $R. Q. = \frac{Vol. CO_2}{Vol. O_2}$, determine the *respiratory quotient.*

3. Does the answer of 2 show that the carbon was stored up as fat, proteids, or carbohydrates?

How Metabolism Is Modified.— The metabolism of the body is subject to various changes, both in degree and kind. The more important conditions are the body at rest, the body at work, the quantity and composition of the food, climatic conditions, weight of the body, age, and sex.

CHARACTER OF FOOD REQUIRED.

The Quantity of Food.— If there be no food taken, as in starvation (*inanition*), the vital processes go on very much the same except in degree. In the first stages the carbon dioxide exhaled decreases, but during the latter part there is but a slight decrease. At first the proteids decrease very rapidly; i. e., the amount consumed until it is less than one half, when it remains constant until a short time before death.

The oxygen taken up during starvation is not so great as in normal conditions, but not so small as the decrease in the amount of carbon dioxide.

There is less carbon consumed and more hydrogen than in normal metabolism.

During starvation there is a loss of body weight, a less vigorous and rapid heart beat, general weakness, but a uni-

[1] Data taken from Schenk and Gürber's Human Physiology (Henry Holt and Co).

form normal body temperature, except just before death when the temperature falls rapidly.

According to Volt's analyses the percentage loss of each organ from starvation is as follows: fat, 97; spleen, 66.7; liver, 53.7; muscles, 30.5; blood, 27; kidney, 25.9; skin, 20.6; intestines, 18; lungs, 17.7; pancreas, 17; bone, 13.9; nervous system, 3.2; and heart, 2.6.

Starvation may result from insufficient food as well as from the absence of food, the time of death due to complete starvation being only delayed in the former case.

1. Lack of Water. — Lack of water will produce death sooner than a lack of solid foods. While water takes no part in the chemical changes, it is essential to the consistency of the tissues and the circulating fluids of the body.

2. Deficiency of Salt. — If the food is wanting in the various salts needed by the body, the excretion of salts steadily decreases, and that of common salt soon ceases altogether, but that of calcium and sodium phosphates continues. As we have seen, a certain proportion of these salts are essential to the life processes. Death finally results from weakness and paralysis.

3. Lack of Organic Food. — If only water and salts are given, the body consumes itself as in complete absence of food, producing the same phenomena, but causing a slight delay in the time of death.

4. Lack of Proteids. — If food containing the proper amount of water, salts, fats, and carbohydrates be taken regularly, as in normal diet; or if these be increased, still, if proteids are lacking or insufficient, the body loses weight, and death results from slow starvation, but coming later. Fats and carbohydrates cannot *protect the body from the loss of proteids.*

If the amount of fats and carbohydrates be large, there may be an increase in the fat stored up in the body even when there is a loss in the proteids. Increase of body weight does not always indicate an improved or healthy condition of the body, as it may result from an abnormal carbohydrate

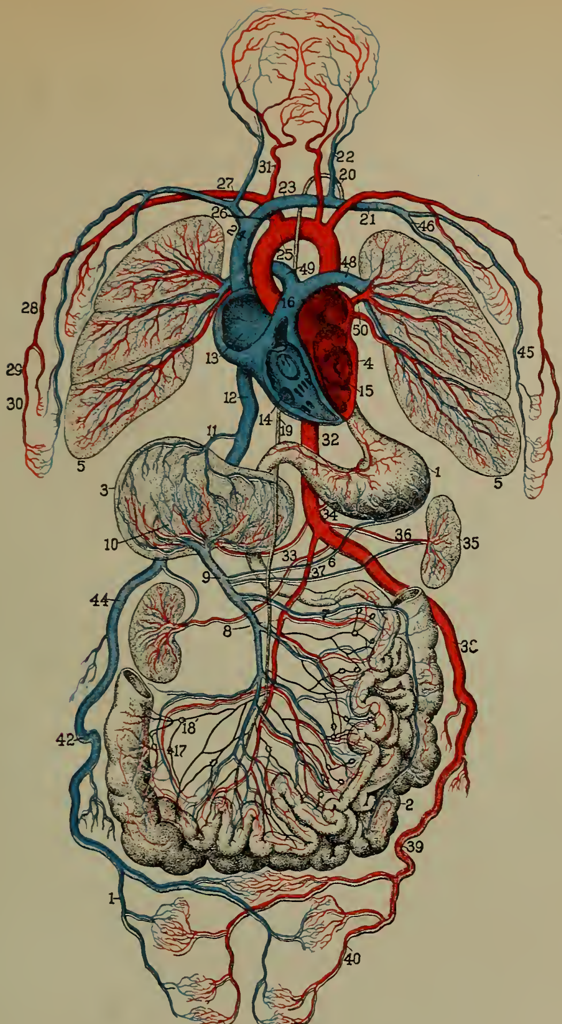


PLATE XIII.

How the Food Gets to the Tissues.

(From Yaggy's "Anatomical Study.")

Fig. 127.—1. The stomach. 2. The intestines. 3. The liver. 4. The heart. 5. The Lungs. 6. Gastric vein. 7. Inferior mesenteric vein. 8. Superior mesenteric vein. 9. Portal vein. 10. Capillaries of portal vein. 11. Hepatic vein. 12. Ascending vena cava. 13. Right auricle of the heart. 17. Mesenteric gland. 18. Lacteal. 19. Thoracic duct. 20. Arch of thoracic duct emptying into left subclavian vein. 21. Left subclavian vein. 22. Internal jugular vein. 23. Left innominata. 24. Descending vena cava. 14. Right ventricle. 16. Pulmonary artery. 48. Left pulmonary artery, whose branches break up into capillaries of the lungs. 50. Left pulmonary vein emptying into left auricle. 15. Left ventricle. 25. Aorta. 26. Right innominate artery. 27. Right subclavian artery. 28. Brachial artery. 29. Ulnar artery. 30. Radial artery. 31. Carotid artery (right). 32. Abdominal aorta. 33. Hepatic artery. 34. Gastric artery. 35. Kidney. 36. Renal artery. 37. Mesenteric artery. 38. Common iliac. 39. Femoral. 40. Branches of femoral artery. 41. Branches forming iliac vein. 44. Ascending vena cava. 45. Cephalic vein. 46. Brachial vein.

and fat metabolism even when the nitrogen nutrition is below the normal.

5. Lack of Fats and Carbohydrates.— While these cannot replace proteids, they may in case of some animals (most carnivora) be replaced by proteids. This, however, is not the case with man, as he cannot digest enough proteids to furnish the extra amount of carbon and hydrogen to take the place of the carbohydrates and fats. Without these an excessive proteid diet leads to emaciation rather than to a gain of flesh or strength.

6. The Proper Proportion of Proteids.— As we have seen, if the amount of proteids taken is equal to the amount used by the metabolism of the body, the nitrogen metabolism is kept up. If, however, the amount of proteid taken be greater than that used up by the body, there will be an increase of the body weight; but this increase of body weight will call for an increase of proteids to be taken, as the amount of proteids required by the body is proportional to the weight, and the nitrogen equilibrium will again be restored. This consumption soon reaches a limit, as a point is reached when the digestive organs are not able to digest the amount necessary to furnish the needed material.

7. The Proper Proportion of Fats and Carbohydrates.— While these cannot take the place of the proteids, when the proteids are wanting in the food, yet, when the body is in nitrogen and carbon equilibrium, they may be increased in amount; they may decrease the amount of proteid consumed by the body, and if the normal diet is kept up, proteids may be stored up by the body. They thus shield the proteids by securing a more economical metabolism.

Effect of Work on Metabolism.— As we have seen, muscular work increases the respiration and circulation; this causes an increase of the consumption of oxygen, and thereby the increase of the respiratory quotient and all the processes of combustion. In moderate exercise the respiratory quotient is the same as during rest. In excessive work the excretion of the carbon dioxide is greater than the oxygen inhaled.

Except where the diet is largely or entirely proteid, the excretion of nitrogen is not increased by exercise, and it would seem that the metabolism is due to the oxidation of the fats and carbohydrates. If the exercise is excessive, there will be an increase of nitrogen, even if the food contains the proper proportion of proteids.

In the work of digestion there is an increased metabolism, and as the excretion of urea is increased, it would seem that the proteids furnish the energy for this process rather than the carbohydrates or fats.

Effect of Climatic Conditions.—As the body must maintain a somewhat constant heat, an increase of external temperature tends to lessen the heat metabolism, and a lower temperature tends to increase[1] heat metabolism, and, as the carbohydrates and fats are the chief source of the heat energy, their metabolism is increased or decreased with the rise and fall of external temperature; i. e., within certain limits.

Effect of Size of the Body, Age, and Sex.—If the surface by which heat is lost be increased, there must be a corresponding increase of heat production. In a small person there is relatively more surface by which heat is lost than in a large one, hence the need of the greater metabolism on the part of the smaller person. Sex of itself seems to have no effect on metabolism.

From a careful study of the principles stated we may deduce the following principles to govern us in the choice and amount of our food:

1. For the adult man the quantity of food needed is: Proteids, 100 grams; fats, 60 grams; and carbohydrates, 400 grams. For the adult woman: Proteids, 90 grams; fat, 40 grams; and carbohydrates, 350 grams. These amounts are required per day.

2. In the working man the amount per day should be: Proteids, 130 grams; fats, 100 grams; and carbohydrates, 500 grams.

---

[1] "The increase of metabolism during loss of heat is caused by a reflex increase in combustion in the muscles, which produces muscular contraction (shivering)."—*Schenck and Gürber's Outlines of Physiology, page 175.*

3. That flesh can only be increased by proteid food, but while this is true, the body is best nourished by a moderate amount of proteids and a large amount of fats and carbohydrates. Exercise favors the laying up of flesh.

4. For the increase of fat, carbohydrates and fats must make up a large proportion of the food.

5. That a mixed diet is best, and that while the body may be nourished by strictly vegetable diet, there is no objection to the use of animal food. Animal foods are better absorbed. The best diet is a proper proportion of each.

6. Each of the three classes of food has its distinct use. A large amount of carbohydrates and a small amount of proteids diminish the amount of proteid required to maintain nitrogen equilibrium. If the proteids are increased, the proteid [1] metabolism is also increased, and although there is a good proportion of the carbohydrates, part of the fat is used up to secure the metabolism of the proteids, and thus the body loses weight. In a continued excess of carbohydrates in our food there is an increase of fat, which results in obesity, interfering with the proper nutrition of the muscles, producing feebleness of the heart and other troubles.

7. The quantity and kinds of food should be adapted to the following conditions: —

a. Climate.—Very slight change is necessary. For warm climates there should be a slight increase in the amount of carbohydrates, the food more easily digestible, and a larger proportion of fruits. For cold climates somewhat more concentrated foods.

---

[1] "*Circulating Proteids.*" — By this term is meant those proteid substances which are dissolved in the blood, lymph, and serous fluids, and by the blood and lymph that are continually circulating through the tissues. They furnish the material for the replacing of the proteid wastes of the tissue.

According to Voit, but one per cent of the organic albumin (of the tissue) is present in the body, while seventy per cent of the circulating albumin is transferred in twenty-four hours."

"Under ordinary conditions only a small amount of the organic albumin, i. e., that composing the tissue, undergoes decomposition, while, owing to the action of the cellular elements of the tissues, a large amount of the circulating albumin is split up, so that under ordinary conditions the organic albumin is comparatively stable." By the stability of the organic albumin is meant that while the cells effect the oxidation of the circulating albumin, and thus set energy free, the cell substance is little affected, and that the greater part of the energy of the proteid metabolism comes from the circulating albumin (proteid); hence, if this is not present in the blood in sufficient quantities to keep up the proteid metabolism, the proteids of the cells must furnish the needed material to keep up the metabolism, and thus the body must live upon its own tissue.

b. Hard Labor.— The increased metabolism demands an increase of all classes of foods making up the diet. Not so great attention is necessary to be given to the digestibility of the food, owing to the increased vigor given to the body.

c. For the Production of Flesh.— The proportion of the proteids should be increased, but with a good proportion of carbohydrates and fats. For the best results gentle exercise is necessary. In training, the entire diet should be increased, as in that for hard labor.

d. For Brain Work.— In this it is not so much a difference in quantity and quality as it is in digestibility. Hard muscular labor gives to the body a vigor which is shared by the digestive organs, enabling them to digest foods when the body is engaged in vigorous work which could not be digested when the body is more passive. Brain work, like muscular work, makes a heavy drain upon nerve force, and demands a large supply of energy; in the former there is not the accompanying vigorous circulation and respiration which give vigor to the entire system; but a passive action of these functions, which lessens the vigor of digestive organs, and demands, therefore, food more easily digested, but possessing high nutritive value.

e. The Person.[1]— In the selection of food the individual is a very important factor, as the amount and kind of the food will be modified by his weight, size, activity of certain organs, and temperament.

Diet Tables.— Various experiments have been made to determine the quantity and proportion of the different classes of food in a normal diet, and from these, various diet tables have been made out. Of these the following from Kirk's Physiology will serve to give an idea of the more important features of a normal diet: —

---

[1] While the child does not require so much food as an adult, he requires more food in proportion to the weight of the body, as there is greater metabolism required to support the growing, as well as the more active metabolism required to support the body heat. The following is required per one kilogram weight of the body:—

Age.	*Proteids.*	*Fat.*	*Carbohydrates.*
2-6 years	3.7 grms.	3.0 grms.	10.0 grms.
7-15 years	2.8 "	1.5 "	9.0 "
Adult	1.6 "	.8 "	8.0 "

(*From Schenck and Gürber, Henry Holt & Co.*)

MOLESCHOTT DIET SCALE.

Dry Food.				*N.*	*C.*
Proteid,	120 grms.	(4.232 oz.)	supplying	18.80 grms.	64.18 grms.
Fat,	90 "	(3.174 ")			70.20 "
Carbohydrates,	320 "	(11.64 ")			146.82 "
				N. 18.80	C. 281.20
Salts,	30 "	(1.05 oz.)			
Water,	2800 "	(2.95 qts.)			

PETTENKOFER AND VOIT'S DIET SCALE.

Proteids,	118 to 137 grms.	(4.1 to 4.8 oz.)
Fats,	56 to 117 "	(1.9 to 4.0 ")
Carbohydrates,	352 to 500 "	(12.1 to 17.6 ")
Salts,	40 "	(1.4 ")
Water,	2016 "	(2.13 qts.)

The composition of our more common foods may be learned by a study of the following table compiled from various sources: —

PERCENTAGE COMPOSITION OF COMMON FOODS.

	Proteids	Fats	Carbohydrates	Water	Salts	Cellulose
I. Animal Food.						
Lean beef..........	20.5	3.5	.9	75.0	1.6	
Fat pork...	9.8	48.9		39.0	2.3	
Smoked ham...... .	24.8	36.5		27.8	10.1	
Whitefish...........	18.1	2.9		78.0	1.0	
Poultry.............	21.0	3.8		74.0	1.2	
Oysters	17.5	0.5		80.0	1.5	
Cow's milk	3.5	4.0	4.0	87.0	0.7	
Eggs.....	12.5	12.0		73.5	1.0	
Cheese..............	33.5	24.3		36.8	5.4	
Butter	0.3	91.0		6.0	2.1	
II. Vegetable Foods						
Wheat flour (white)	11.0	2.0	70.3	15.0	1.7	0.5
Wheat bread	8.0	1.5	49.0	40.0	1.2	0.3
Oatmeal............	12.6	5.6	63.0	15.0	3.0	1.6
Maize.	10.0	6.7	64.5	13.5	1.4	1.5
Rice................	5.0	0.8	83.2	10.0	0.5	4.0
Potatoes	2.0	0.16	21.0	74.0	1.0	1.0
Beans	24.5	2.0	52.0	12.5	3.5	6.0
Cabbage............	1.8	5.0	5.8	91.0	0.7	1.5
Fruit................	0.5		10.0	85.0	0.5	4.0
Sugar...............			96.5	0.3	0.5	

Problems.— 1. From what has been given determine if the following would be the proper daily diet for a person twelve years of age; potatoes, 60 grams; eggs, 10 grams; lean beef, 100 grams; wheat bread (white), 60 grams; butter, 1 gram; fruit, 10 grams; and water, 2,000 grams. Would the above be a good diet for an adult engaged in hard manual labor? If not, what modification should be made?

2. Make out a daily bill of fare for a child of ten years.

3. Make out a daily bill of fare for an adult student.

4. Determine the relative value of 100 grams of rice and 100 grams of fat beef (stearin).

5. If an adult person eats 85 grams of butter, how many grams of wheat bread are required to keep up the carbon equilibrium?

6. If a laboring man eats 350 grams of wheat bread (white), 10 grams of fruit, 50 grams of eggs, how much lean beef will be required to keep up the nitrogen equilibrium?

The amount of carbon or hydrogen in a substance may be determined as in the following example: How much carbon is there in 50 grams of grape sugar? The formula for grape sugar is $C_6H_{12}O_6$ (see page 316). First find the molecular weight; viz.: —

C_6 = 12	atomic weight	× 6	= 72
H_{12} = 1	" "	× 12	= 12
O_6 = 16	" "	× 6	= 96
Molecular weight			180

Second, determine the percentage of carbon by proportion; viz., (1) for C, it would be 180 (molecular weight) : 72 (weight of the carbon) : : 100 (the base of comparison) : per cent of C (40 per cent in this case) required; (2) for H it would be 180 (molecular weight) : 12 (weight of the hydrogen) : : 100 (base of comparison) : per cent (6.6 in this case) H required, one third the number of grams of carbon or hydrogen; viz.: (1) for the C it is 100 (base) : 40 (per cent) : : 50 grams (weight of the sugar) : number of grams of C (in this case 20) required; (2) for H it is 100 (base) : 6.6 (per cent) : : 50 grams (weight of sugar) : number of grams of H (in this case 3.3) required.

The amount of hydrogen and carbon in the fat may be determined by the same method.

[2] The amount of nitrogen in a proteid may be determined by dividing the weight of the proteid by 6.5, and conversely the amount of proteid may be determined by multiplying the weight of the nitrogen by 6.5.

CHAPTER XII.

ANIMAL HEAT.

EXPERIMENTS AND DEMONSTRATIONS.

1. Over a lighted alcohol lamp support an inverted funnel so that it will collect the gases resulting from the burning of the alcohol, and connect the tube of the funnel with a glass of lime water so that the gases collected will pass into the water. Does the lime water change color, and is there a precipitate formed? Is carbon dioxide formed by the burning of the alcohol? Do drops of water collect on any part of the funnel? Alcohol (*ethyl alcohol*) has the formula of C_2H_6O, and if to one molecule of alcohol there be added six atoms of oxygen, can you account for the formation of the carbon dioxide (CO_2) and water (H_2O)?

2. Prepare two fruit jars of *dry* chlorine[1] gas. In the first jar drop a piece of cotton soaked with spirits of turpentine; note the combustion that takes place. In the second jar sprinkle some finely powdered antimony. Notice the results. In each case the heat is produced by chemical change, but in the latter case it is not oxidation, but the vigorous union of the chlorine and antimony.

3. Fit a 250 c.c. flask with a two-holed cork. Through one of the holes pass a thistle tube so that it will just reach the bottom of the flask, and in the other hole insert a jet-tube bent at an obtuse angle (about 140°), so that the jet points outward from the thistle tube. Place in the flask 20

[1] Chlorine gas may be made in the following manner: place in a flask, fitted with a rubber cork and a rubber delivery tube, 20 grams of black oxide of manganese (*manganese dioxide*) and 80 c.c. of strong muriatic acid (*hydrochloric acid*); connect the delivery tube with one arm of a U-shaped calcium chloride tube (which should be half full of pieces of calcium chloride), and from the other arm of the U tube run a rubber tube into the mouth of a quart fruit jar, letting the tube go to the bottom of the jar. See that all the connections are tight. Heat the flask *gently*. The chlorine gas being heavier, will displace the air. The chlorine gas may be told by its greenish yellow color. ***Avoid breathing the chlorine.*** As you remove the jars of chlorine as they are filled, which may be told by the yellowish green gas, cover them with squares of cardboard or glass. Four or five jars will be enough for the experiment.

grams of granulated zinc; cover it with water to the depth of three centimeters. Cork the flask, and see that the end of the thistle tube is below the water in the flask. Add sulphuric acid gradually through the thistle tube until there is a brisk effervescence of the water. Feel the bottom of the flask from time to time as you add the acid to see if there is any increase of temperature. When the apparatus has been working freely for a few minutes, light the jet. If the effervescence lessens, add more acid. Hold over the jet an inverted tumbler or small bell-jar. What is it that collects in drops on the side of the glass? If the gas formed in the flask is hydrogen, and the gas joining with it is oxygen from the air, can you explain the formation of the water on the sides of the glass? What causes the flask to get warm on the addition of the acid to the water?

The burning of the hydrogen is a case of oxidation, but the product is not carbon dioxide, but water. The chemist represents the action thus: $H_2 + O = H_2O$.

Two atoms of hydrogen + one atom of oxygen = one molecule of water.

What would the combustion of the hydrogen in the body form? Where would the oxygen come from? Suppose the glycogen of the muscles should be completely oxidized, it having the formula of $C_6H_{10}O_5$. If it oxidizes into CO_2 and H_2O, does it contain enough oxygen to join with the hydrogen? How many atoms of oxygen will be needed to use up the C?

Have fats enough O to use up the H they contain, if they have the formula of $C_{57}H_{104}O_6$, remembering every C will require two O for the formation of CO_2, and every two H one O to form H_2O? Which make the greatest drain on the oxygen of the blood, fats or carbohydrates?

4. By means of a glass tube or wheat straw breathe into a glass of lime water. What evidence have you that the breath contains carbon dioxide? Where did the carbon dioxide come from? What change does this indicate is taking place in the tissues?

5. Pour fifteen or twenty drops of ether in the palm of the hand, holding the hand so that you will not breathe the ether, and notice the cooling sensation produced by the evaporation of the ether. Try in the same way some alcohol. What difference do you notice? What effect has the rate

of evaporation on the degree of cold produced? Would water evaporating rapidly from the surface of the skin produce a similar effect as the ether and alcohol?

6. When the water in the teakettle is boiling rapidly, remove the kettle from the stove, and at once place the hand on the bottom of the kettle. Notice that the bottom of the kettle is not very warm. As long as the water boils there is no danger of burning the hand. Notice that when the water ceases to boil the kettle begins to get warmer. How do you explain the fact that the bottom of the kettle is not hot while the water boils, but becomes so as soon as the boiling ceases?

In passing from the liquid condition to steam the water passes into gaseous condition; to do this heat is required, which it takes from the kettle which readily gives up its heat.

How does a breeze of fanning cool the body?

7. If you do not have in the apparatus of the school a clinical thermometer, borrow one of a physician, and make the following observations: —

a. Determine your own temperature by placing the bulb of the thermometer under the tongue; keep it in the mouth for a few minutes, and then notice the temperature.

b. Determine your temperature by placing the bulb of the thermometer in the armpit (*axilla*).

c. Take your temperature immediately on rising in the morning; just after breakfast; just before dinner, and one or two hours after dinner; just before retiring at night.

d. Take your temperature when in a warm room; when out in the cold.

e. Take your temperature while at rest, then engage in some vigorous exercises until you begin to perspire, and again determine your temperature. Do you notice any rise in the last case? Let several persons try these experiments, and compare results.

8. Put 50 c.c. (about 40 grams) of 95-per-cent alcohol in an alcohol lamp. Place 500 c.c. of ice water in a flask, and heat the flask by means of the alcohol lamp for ten minutes. Take the temperature of the water. Determine how many grams of alcohol have been used in warming the water. Determine by the following formula the calories of heat produced by the combustion of the alcohol: —

$$\frac{\text{500 c. c. of water at } 0°\text{C.} \times \text{temp. of water at close of exper.}}{1000} = \text{number of calories.}$$

This will be approximately true if the water does not boil. Each gram of absolutely pure alcohol will give 220 calories of heat.

9. *Problems: a.* How many calories of heat will 20 grams of sugar give when completely oxidized, on the following basis: 1 gram hydrogen on burning yields 34 calories; 1 gram carbon, 8 calories?

b. Which will yield the more heat, 10 grams of fat (1 gram fat = 9.3 calories) or 25 grams of sugar (1 gram = 3.7 calories)?

ANIMAL HEAT.— TEXT.

Need of Heat to the Body.— We have been considering the various metabolic processes of the body, and have learned that these may consist of those by which tissue is formed and of those in which energy is set free for muscular motion, nerve force, and heat. In the constructive processes (*anabolism*) heat is absorbed, but in the destructive processes (*katabolism*) heat is set free. Heat is needed to make up for the loss due to constructive metabolism. Heat is also needed to maintain the proper temperature for the various metabolic processes, as without this temperature these changes will not take place. The body is constantly losing heat by radiation, and it is in a medium which is sometimes of a lower and sometimes of a higher temperature than itself; it, therefore, needs heat to make up for the loss by radiation, and also some means of adapting itself to the changeable temperature of its surroundings.

Sources of the Heat of the Body.— The heat of the body is due to various destructive metabolic processes, which for the greater part are of the nature of oxidation, in which the carbon and hydrogen of the substance are acted upon by the protoplasm of the tissue, or by the protoplasm itself, by which there is ultimately formed carbon dioxide and water. The more active[1] these changes, the greater the heat produced, and the larger the amount of carbon dioxide and

[1] One kilogram of coal yields the same quantity (same number) of calories, when oxidized slowly, as when oxidized rapidly; but if two kilograms are consumed in one minute, they will produce twice the amount of heat for a unit of

water formed. We should use the expression, "that the heat is produced by the metabolic changes of the tissue," with caution; if by the statement we mean that the process consists in the tearing down of the protoplasm of the tissue, by the destruction of which the heat is produced, the statement is questionable. It is true that the protoplasm of the cell is the agency by which these oxidations are effected, but there is a question as to the protoplasm being the product from which the carbon dioxide and water are produced and the energy set free. There is no doubt that a very small part of the protoplasm of the cell may be used up in this process, but by far the greater part of the energy is produced by the oxidation of the substances furnished by the blood and lymph.

The Tissues Producing Heat.— In any tissue in which destructive metabolism takes place, heat is produced. The tissues differ greatly in their activity, and there will be a corresponding difference in the heat they produce. The more important heat-producing tissues are,

1. *The Muscles.*— The muscles, as we have learned, are very active tissues, giving off carbon dioxide during rest, as well as during muscular contraction. As they make up a large part of the body, and are very active tissues, they may be considered the chief source of the heat of the body. Even if we should disregard the heat produced by the quiet metabolism of the muscular tissues, it has been estimated that the heat produced by the muscular contractions would supply the principal part of the heat produced in the body.

2. *The Secreting Glands.*— In the process of secretion, active metabolism takes place, and the heat thus produced

---

time, and hence a greater temperature than if set free in two minutes, although in each case there will be the same quantity of heat produced. It is the rate of oxidation that determines temperature.

Clearly distinguish between quantity of heat and temperature. A pint of water may have a higher temperature than a hogshead of water, but it has a much less quantity of heat. Temperature is determined by the thermometer, and indicates the kinetic energy of the molecules, while quantity of heat means the total kinetic energy of the entire mass, and is determined by the product of the mass by the temperature. One gram of water at +100° C. has the same amount of heat as 50 grams of water at + 2° C., although the first is 98° C. hotter.

will depend on their size, activity, and on the constancy of their action. As the liver is the largest and most active of the secreting glands, it produces the most heat. Its large size and constant activity place it next to the muscles as a source of the heat of the body. The blood on leaving the secreting glands is much warmer than it is on entering the glands.

3. *The Brain.*— The cellular elements of the nerve tissue are engaged in active metabolic changes. We should expect, therefore, that the brain (the chief mass of cellular nerve substance), by its size and constant action, would give to the body considerable heat. That this is true is shown by the fact that the venous blood of the brain has a higher temperature than the arterial.

The Loss of Heat.— There are various sources of the loss of heat; the more important are —

1. *By Mechanical Work.*— Of the energy set free by an organism, one fourth may be used up in mechanical work, and three fourths set free as heat. In estimating the amount of available energy in a given amount of proteid, fat, or carbohydrate, this must be taken into consideration, as the energy used in mechanical work is lost as far as raising the temperature of the tissue and blood, and cannot therefore be a source of heat to the body.

2. *From the Surface of the Body.*— This is by far the most important source of loss of heat, which takes place by radiation, conduction, and evaporation from the skin. This loss is due to the large surface presented by the skin for radiation and evaporation, and its large blood supply. Of this loss for every 100 calories of heat produced by the body, 14.7 are lost by evaporation and 80.1 by radiation and conduction.

3. *From the Lungs.*— When we consider the amount of surface[1] exposed by the mucous surface of the lungs, it would

[1] The air cells of the lungs, if spread out side by side, would cover an area of 2,600 square feet; if we add to this the surface exposed by the bronchial tubes and their numerous divisions, the surface exposed to loss of heat would be very much increased. To get the full surface exposed to loss we must add to that of

seem that this source of loss would be considerable; yet, while next to the skin in importance, it is comparatively small. This is due largely to the fact that air inspired is heated by its passage through nasal fossæ, pharynx, trachea, and bronchi, and is near the temperature of the blood before it reaches the lungs. If the depth and rate of the respiration be varied, the loss of heat will be somewhat modified. The loss by the lungs is 2.6 calories for every 100 produced.

4. *By Warming Cold Foods.*— While this loss will vary with the temperature and quantity of the food, it is estimated to be 2.6 calories for every 100 of heat produced.

If a large amount of cold liquids, as iced tea or water, be taken, the loss is very much increased.

The Quantity of Heat.— The quantity of heat produced by the body will vary with the activity of the tissues and the quality and quantity of the food. In the resting adult it has been estimated at 2,400 calories per day or 100 calories per hour. In the resting adult of average weight this amount gives us thirty-four calories in twenty-four hours for each kilogram of body weight. By vigorous exercise this amount is increased to fifty-five calories for the same time.

The heat-producing power of the foods varies even with a corresponding activity of the tissue. In complete[1] oxidation the heat values of the different classes of foods have been estimated to be as follows: 1 gram of proteid, 4.1 calories; 1 gram of fat, 9.3 calories; 1 gram of carbohydrates, 4.1 calories. The heat value of carbon is 8 calories; of hydrogen, 34 calories.

---

the lungs the surface of the mucous membrane of the bronchi, trachea, larynx, pharynx, and nasal fossæ. It is in the upper part of the course of the air passages that most of the heat is lost. Taking in the entire air passages, it has been estimated that the loss here is fifteen per cent of the whole.

[1] From what has been said, it might be inferred that the process of oxidation in the tissue is a simple one, and that the proteids break down at once into urea, carbon dioxide, and water, and the carbohydrates and fats into carbon dioxide and water. The oxidation of these substances is, in fact, very complex, and there are many transitions from the carbohydrate and the final products of its oxidation, carbon dioxide and water. The same is true of the oxidation of fat. Proteids are not completely oxidized in the body. Urea, the principal end product of proteid oxidation, is still capable of oxidation, and the estimate given above for the oxidation of proteids is the heat value of proteids less that of urea.

Equalization and Control of the Heat.— The equalization of the heat is secured principally by the blood in its constant circulation from the more highly heated parts of the body to those of lower temperature, where the blood is cooled. On its return to the heated parts the blood tends to cool them, and by this constant exchange between the warm and the cool parts the heat is equalized.

The control of the temperature of the body is due —

1. *To Regulation of the Production of Heat.*— This is secured chiefly by the regulation of the metabolism of the cells which is effected by the nervous system. Some physiologists think there is a special heat center by which this is controlled; others think the influence of the nervous system is only indirect, in that it affects the blood supply through the vasomotor nerves, and thus, by increasing the amount of blood in the tissue, increases or retards the metabolism of the tissue. Aside from the effect produced by the influence of the vasomotor nerves, there is both experimental and clinical evidence which indicates the existence of one or more heat centers similar to those which regulate the flow of the saliva and other secretions. These centers have not been located.

2. *By the Regulation of the Loss.*— This is secured (*a*) by the use of proper clothing, which regulates the conduction and radiation of body heat; (*b*) by the perspiration, which regulates the loss by evaporation; (*c*) the depth and rate of the respiration, deep respiration increasing the loss.

Effects of Extreme Temperature.— The temperature of the body remains in normal conditions the same, notwithstanding the variable external temperature. The temperature of a person in a torrid climate is within a degree Centigrade of that of a person in a frigid climate. Persons have remained for some minutes in dry air in which the temperature was between 92° and 100° C., and persons have entered furnaces in which the temperature was 205° to 315° C. Such temperatures cannot be endured if the air is moist.[1]

[1] "C. James states that in the vapor baths of Nero, he was almost suffocated in a temperature of 44.5° C., while in the caves of Testaccio, in which the air is dry, he was but little incommoded by a temperature of 80° C." — *Kirk.*

These instances of adaptation to extreme temperature illustrate the perfection of the heat-regulating apparatus of the body. An increased loss of heat within certain limits produces an increased metabolism, and this in turn makes a demand for more food to furnish material to support the increased metabolism. The cold also causes the contraction of the blood vessels, which lessens the blood supply and the activity of the perspiratory glands, and thereby reduces the loss by conduction and evaporation. But there is a limit to this adaptation, so that the deficiency must be made up by clothing which further reduces the loss, and by the increased metabolism by which the body maintains its equilibrium of temperature. If the external temperature be greater than that of the body, the decreased loss tends to lessen the metabolism. The higher external temperature also causes the blood vessels to dilate, increasing the blood supply, and thus exposing more blood to the surface of the body to lose heat by radiation and conduction; and at the same time, through the nervous mechanism of secretion and the increased blood supply, the activity of the perspiratory glands is increased, and thereby the loss of heat by evaporation increased. If, however, the atmosphere be humid, the air near the body soon becomes saturated with moisture, which checks the evaporation from the body, and thereby the loss of heat. The heat thus accumulates, and the body soon suffers from the intense heat.

Normal Temperature of the Body.— From childhood to old age, through all seasons of the year, in arctic or torrid clime, at work or at rest, the body temperature remains practically constant,[1] varying one-half or one degree above or below 37° C. (98.6° F.).

Fever may result from various causes, as specific germs,

[1] Under morbid conditions the temperature of the body may rise above the normal. A rise above 37.2° C. (99° F.) indicates a feverish condition; 37.7° C. (100° F.) to 38.7° C. (102° F.), a moderate fever, 40° C. (104° F.) to 41.1° C. (106° F.), a high fever, and if the temperature of 41.6° C. (107° F.) or 42.2° C. (108° F.) is reached, and it be continued, death will soon result.

The heated blood causes a great increase of the number of heart beats and respiratory movements until exhaustion is produced.

congestion, and inflammation. But from whatever source, the increased temperature is mainly due to an increased heat production without a compensating loss of heat.

The increase of the amount of carbon dioxide and urea excreted indicates an increased metabolism. This increased metabolism seems to produce a greater tissue waste than normal metabolism, not only from the want of food, but also from the increased susceptibility of the protoplasm of the cells to change; and the energy produced is set free as heat, and is not available as energy for mechanical work; hence the weakness and loss of flesh due to fever.

CHAPTER XIII.

THE MUCO-DERMAL SYSTEM.

EXPERIMENTS AND DEMONSTRATIONS.

1. Examine a prepared section of the human skin, (*a*) with three-fourths objective. How many distinct layers do you notice? Make a careful drawing. Compare with Fig. 145, and determine names of parts. (*b*) Examine different portions of the slide with one-eighth or one-sixth objective. How many layers can you recognize? Compare with Fig. 144.

2. Make a vertical section of the eyelids of the cat. Harden by keeping in a twenty-five-per-cent solution of chromic acid for six or seven days; transfer to eighty- or ninety-per-cent alcohol, prepare a section as directed in Appendix. Examine as directed in Experiment 1.

3. Make a vertical section of the skin of a rat, and prepare as given in Experiment 2. Examine as directed in Experiment 1. Study and determine name of parts observed.

4. Treat a fresh hair with concentrated acetic acid, which will bring to view the cuticle and the parts of the medulla. (*a*) Examine with low and high power objectives. (*b*) Treat some fresh hair with sulphuric acid by heating in the acid at a temperature 40°–50° C. for an hour. This will isolate the plates of the cuticle and the fiber cells of the substance of the hair. Examine as before. (*c*) The elements of medulla may be very clearly seen by soaking the hairs in a two-per-cent solution of caustic potash for several days. Make drawings of what you observe. (*d*) Examine hair of different animals, and compare.

5. Take a piece of the skin from the ball of the foot of a cat, harden in chromic acid and alcohol. Note (*a*) the terminal gland coil in the outer part of the subcutaneous tissue. Are they all located at the same level? (*b*) the gland duct. Determine parts by comparing with Fig. 144.

6. Examine the palm of the hand with a reading glass or a Coddington magnifier of three-fourths-inch focus. Notice the number and arrangement of the pores.

7. When perspiring freely, notice the condition of the blood vessels. What reason can you give for this condition? Collect a few drops of the perspiration. Test first with blue litmus paper, then with red litmus. What is its reaction? Examine a drop of perspiration with the microscope.

8. Dip a platinum wire (No. 30) ending in a small loop and about two inches long in some perspiration, and then hold the loop in the nonluminous flame of a Bunsen burner or candle. If it colors the flame yellow, it indicates the presence of sodium in the perspiration. Look at the flame with a blue glass; if the flame appears purple, it indicates potassium. To fifteen or twenty cubic centimeters of perspiration add a few drops of a solution of silver nitrate. If you get a white precipitate, it indicates the presence of a chloride. This in connection with a yellow flame shows the presence of sodium chloride.

9. To 10 c.c. of perspiration add 5 c.c. of baryta water, filter, and to the filtrate add, drop by drop, a solution of nitrate of mercury until the precipitate gives a yellow reaction with sodium carbonate, which indicates the presence of urea.

10. To 5 or 10 c.c. of perspiration add a few drops of barium chloride; the formation of a white precipitate indicates the presence of sulphates.

11. To 15 or 20 c.c. of perspiration add 5 or 10 c.c. of lime water; if the solution becomes turbid, or there is formed a white precipitate, it indicates the presence of carbon dioxide. Write a summary of what you have learned in these experiments about the composition of perspiration.

12. Place the hand in a clean quart glass fruit jar or bell-jar; cover the mouth of the jar, and the portion of the hand outside of the jar, with sheet rubber so as to exclude the air from the jar. Keep the hand in the jar as long as you can. Keep the jar moderately cool.

What is the source of the moisture that collects on the side of the jar? What do you learn from the experiment?

13. Place the hand for a few minutes in warm water 38° C., then for the same length of time in cold water 4° C. How do you account for the different appearance of the skin in each case?

14. (Problem.) If the total number of sweat glands is 2,500,000, and their average length is one fourth of an inch,

how long a tube would they make if put end to end? Give your answer in miles. What would be their total caliber if they were placed side by side, if the pores by which they open is one six-hundredth of an inch in diameter? Give your answer in square feet.

15. Put a few drops of ether in the hand, and notice the sensation produced by its evaporation. How do you account for the cool sensation?

16. When the water in the teakettle is boiling, remove the kettle from the stove and place your hand on the bottom of the kettle. Why does it not burn the hand? What effect would the evaporation of the perspiration have upon the temperature of the skin?

17. Examine the teeth of an adult. How many are there? How do they differ in size and form? As to their form, into what four classes can they be grouped? How many teeth are there in each group? Determine from the text names of the four classes of teeth. What reason can you give for the difference in the shape of the teeth? Do you see any reason for the teeth of an ox being different from those of a dog?

18. Examine the teeth of a child six or seven years old. What difference do you note in the number and form of his teeth? Into what classes can they be grouped? What name is given to the teeth of the child? Why do children shed their teeth? What name is given to the teeth of the adult?

19. Secure from the dentist some teeth, and compare the structure of the *milk teeth* with those of the *permanent teeth*. Compare the form and size of the incisors, canine, bicuspids, and molars, and note how they are adapted to their respective function.

20. Examine, and by a study of Fig. 147 determine the parts of a tooth.

21. Examine longitudinal and cross sections of teeth, and determine their structure. How do the different parts differ in hardness? Will the upper hard part of the tooth scratch glass? Why is it so hard? Make thin vertical and cross sections of a tooth, and examine with the microscope.

22. Examine the skeleton, and determine how the teeth are set in the jaws. How do the nerves and blood vessels go to the teeth? What is the purpose of the hole in the fang of the tooth? of the cavity of the tooth?

23. Determine the composition of the teeth in the same manner as you did for that of the bone. Which has the more water? Which the more carbonates? Test the teeth for silicates (see Appendix).

THE MUCO-DERMAL SYSTEM.—TEXT.

The Skin.—The covering of the body is called the skin (Fig. 142). At the orifices of the body, as the mouth and nostrils, and some other parts, it becomes gradually blended with the mucous membrane that lines the interior of the body. As we have seen, the skin and the mucous membrane are very much alike, each being made up of an outer cell layer resting upon an inner fibrous layer. Each has its own modification, however, to adapt it to its peculiar function.

The thickness of the skin varies in different parts of the body; where exposed to pressure and friction, as on the soles of the feet, and in the palms of the hands, it is much thickened. The skin is elastic, and tends to adapt itself to the change of form in the organ it invests. When viewed under low power, the skin is seen to be composed of two layers: an outer, cellular layer, the *epidermis;* and inner, fibrous layer, the *derma.*

The Epidermis, or Cuticle.—The epidermis (Fig. 12) consists of (1) the superficial horny layer of flattened cells; (2) a layer formed of dense, horny scales showing traces of a nucleus, the *stratum lucidum;* (3) a layer consisting of several layers of nucleated cells, the deeper ones of which become columnar as they rest on the underlying corium or dermis, the *rete mucosum.* It is in the deepest parts of the cell layers of the epidermis that the new cells are formed by cell division. The cells are pushed outward from below, and as they near the surface, they not only become compressed and changed in shape, but they undergo a change in chemical composition, their protoplasm being converted into a horny substance (*keratin*). Before their transformation into the horny layer, there is usually a deposit of granular material within the cells, which gives a granular appearance to the upper layers of the *rete mucosum.* The color of dark-col-

ored races is due to pigment granules contained chiefly in the cells of the deeper layer of the *rete mucosum*. The older cells are constantly being removed by wasting and friction, and constantly renewed from below.

The Dermis, or Corium.— This layer is also called the true skin (Fig. 144), or *cutis vera*. It varies in thickness in different parts of the body, being from one twelfth to one eighth inch in some cases, in others only one hundredth, as

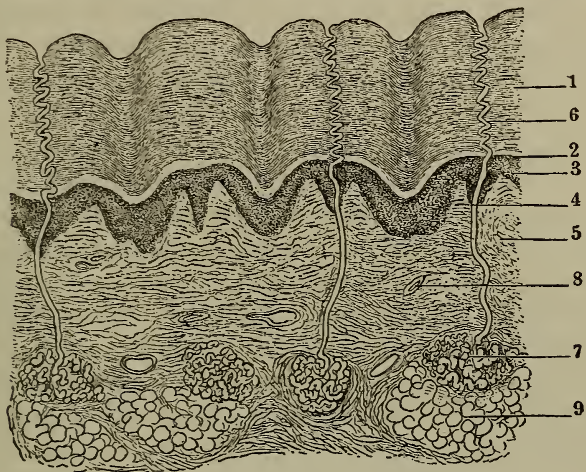


FIG. 142.— VERTICAL SECTION OF THE SKIN.

1. Outer horny layer. 2. Stratum lucidum. 3. Rete mucosum. 4. Papilla. 5. The corium (derma). 6. Duct of sweat gland. 7. Sweat gland. 8. Artery. 9. Subcutaneous fat.

in the lips and ear passages. It is made up of an interlacing network of white, fibrous connective tissue, with some elastic fibers, numerous blood vessels, lymphatics, and nerves; and gradually becomes blended below with the subcutaneous tissue, through a layer of areolar tissue of varying thickness containing fat cells. On its upper surface are numerous small projections (*papillæ*) which protrude up into the epidermis, the innermost layers of the epidermis being molded over the papillæ, and forming processes between them. The papillæ are very sensitive, and consist of vascular eminences, conical or club-shaped, about one hundredth of an inch in height, which contain capillary loops; most of them have

also one or more nerve fibers, those of the hands and feet ending in a touch corpuscle. Fine nerve fibers also pass into the epidermis, where they end between the cells or in the deep epithelium.

On the general surface of the body the papillæ are comparatively few in number, but in sensitive parts, as the palm of the hand and fingers, they are numerous. On the palm of the hand they are arranged in parallel curved lines, forming the elevated ridges seen on the free surface of the skin.

The Sweat Glands.— The sweat glands, called also sudoriferous glands, are found in the human skin in nearly all parts of the body, their total number being over 2,500,000. They are most numerous in the palms of the hands and the soles of the feet, and largest in the axillæ and groin. They are comparatively few in the neck and back. The pores, or openings, of the ducts are about one six-hundredth of an inch in diameter, and are visible with a lens of moderate power. Each gland consists of a single tube with a closed end, forming a closed coil about one sixtieth of an inch in diameter, situated in the deep part of the dermis or in the subcutaneous fatty tissue. This is the secreting portion of the gland, and is surrounded by a network of blood vessels. From the coil the duct passes upward in a somewhat wavy course through the dermis, but takes a spiral direction on entering the epidermis upon whose surface it empties.

The secreting portion consists of a fine basement membrane, a layer of longitudinally disposed fibers, which are usually considered muscular, and a single layer of columnar epithelium lining the central cavity.

The conducting tube, which includes about one fourth of the coiled part, has a basement membrane of epithelium of two or three cell layers, an internal delicate lining, and the tube, or lumen. It has no muscular layer, and the tube is smaller than the secreting portion. In its passage through the epidermis, it is only a channel through the epithelial cells.

The Sweat, or Perspiration.— The secretion of the perspiratory glands is called sweat, or perspiration. It consists

of 98.8 per cent water, 1.2 per cent of solids in solution, a few shed scales of the epidermis, and a small amount of sebaceous material. The chief solid products are sodium chloride, fats, and fatty acids, and traces of urea. When scanty, its reaction is acid; but when abundant, alkaline. The amount of carbon dioxide given off by the skin is very small, being only ten grains in twenty-four hours, while a corresponding amount of oxygen is absorbed. Cutaneous respiration in man and other mammals is, therefore, very slight. Rabbits or other mammals covered with gold foil or coated with varnish to prevent the escape of the perspiration, do not die from the effect of the carbon dioxide not being excreted, as was formerly supposed, but rather from excessive loss of heat by too rapid radiation.

If wrapped in cotton, the animal will live for some time. In such animals as the frog, which have a thin skin, the cutaneous respiration is of much importance.

When the secretion of the perspiration is small, it passes off as rapidly as formed, and is called insensible perspiration. If the amount is large, or if it forms in drops due to its forming more rapidly than it evaporates, it is called sensible perspiration. The amount of sensible perspiration is influenced by the humidity of the atmosphere, the temperature, and the muscular exercise. The total amount of perspiration secreted in twenty-four hours by a man is nearly 1,000 grams, or over 2.2 pounds.

The blood vessels have the power of changing their caliber: by dilating, they bring to the part more blood; by contracting, they reduce the amount of blood. As we shall learn, this power to change the size is under the control of the nervous system. An increase of blood supply tends to increase the activity of the secretions in the sweat glands. In addition to this source of increasing the amount of perspiration, there are parts of the spinal cord, the direct stimulation of which produces an increased flow of the perspiration. These parts are known as sweat centers. There are drugs and agents which affect these centers which the physicians give when

they want to produce sweating. These drugs and agents are called *diaphoretics*, as hot baths (98°–100° F.), hot teas, alcohol, pilocarpine, and sweet spirits of niter.

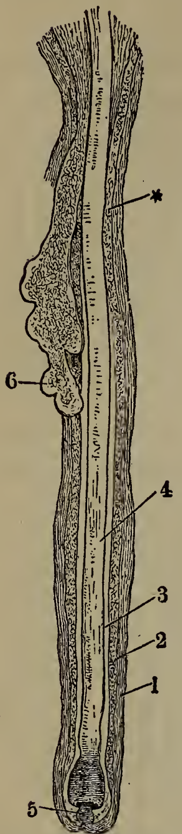


FIG. 143.—HAIR AND HAIR FOLLICLE AND SEBACEOUS GLAND.
1. Outer sheath. 2. Inner sheath. 3. Hair follicle. 4. Hair. 5. Papilla. 6. Sebaceous gland.

The sweat glands act as excreting organs. They remove from the system, water, mineral salts (principally sodium chloride), fats, acids, and some urea and carbon dioxide.

There is a close relation between the activity of the kidneys and the skin. When the skin becomes inactive, it throws more work on the kidneys, and conversely inactive kidneys make a greater demand on the skin.

The perspiration aids in regulating the temperature by its evaporation. How this is done you may learn by Experiment 15.

Functions of the Skin.— The more important functions of the skin are, (1) to protect the delicate parts of the body; (2) to prevent too rapid radiation of the heat of the body, which would take place were it not for the skin being a poor conductor of heat; (3) to regulate the temperature of the body by means of the perspiration, also by controlling the amount of blood exposed to loss of heat by means of the contraction or dilation of the cutaneous blood-vessels; (4) to act as an organ of absorption, as water and a number of substances may be taken up by the skin; (5) to remove waste materials from the body by means of its excretions; (6) to sever as an organ of the sense-touch, some of the papillæ of the skin containing the end organs of the nerves of touch; (7) to secrete the perspiration and the sebaceous material for the protection of the skin and hair.

Hair and Nails.— These organs are modifications of the epidermis. *The hair* is developed in pits which often extend down into the dermis. The parts of the hair (Fig. 143) are the root, the part found within the follicle, and the shaft, or the free portion. The root consists of soft growing cells fitting over a vascular papilla. The shaft is made up of a central pith, or medulla (Fig. 144), formed of angular cells. This layer is sometimes absent. The fibrous part consists of long, tapering cells united to form fusiform fibers. This layer forms the chief part of the hair. The outer layer is called the cortex, or cuticle. It consists of thin, flat cells overlapping each other.

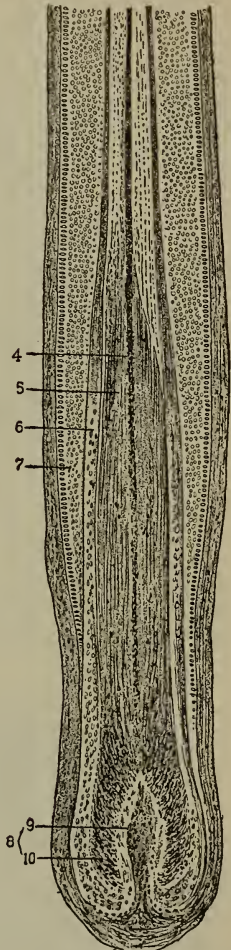


FIG. 144.—VERTICAL SECTION OF HAIR FOLLICLE WITH HAIR.

4 and 5. Medulla. 6. Inner root sheath. 7. Outer root sheath. 8. Bulb. 9. Papilla. 10. Root.

The pit, or follicle, is formed by two coats; an outer, or dermic, continuous with the corium of the skin; and an inner, or epithelial, called the root sheath. The hair grows from the bottom of the follicle by the multiplication and elongation of cells covering the papilla. Connected with the papilla are small bundles of muscular fibers (*erectores pili*), which pass from the corium to the bottom of the follicle. By their contraction they not only erect the hair, but also raise one part of the surface of the skin, and depress another.

Sebaceous Glands. – The sebaceous glands are simple sac-shaped glands found all over the surface of the body, except in the palm of the hand and soles of the feet. The duct usually opens into a hair follicle (Fig. 143), though some, in a few situations, open free on

the surface of the skin. Both the duct and the sac of the gland are lined with secreting cells, some of which become charged with fatty matter. Excretion appears to take place by the rupture or disintegration of the loaded cells, the transformed cells and their contents being pushed out of the duct through the hair follicle on the surface of the skin by the new cells from behind. The excretion[1] (or probably more properly the secretion) appears when fresh to be an oily substance that sets, on cooling. It is made up of fatty particles, crystals or organic substances, and epithelial cells.

The Nails are implanted in a groove in the skin by a portion called the root, and grow from a portion of the true skin called the bed, or matrix. The nail consists (Fig. 145, A and B) of horny cells having a laminated structure, the deepest layers lying in contact with the papillæ of the matrix. The nail grows by the formation of new cells at its root, and on the under surface.

The Teeth.—When functionally considered, the teeth should be classed with the digestive apparatus; but when considered as to their origin and structure, they belong to the same system of organs as the skin and mucous membrane, and are to be considered as modified epithelial growths.

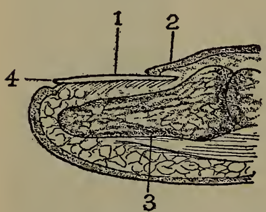


FIG. 145.—THE FINGER NAIL. VERTICAL SECTION OF FINGER.
1. Body of nail. 2. Wall or covering of root of nail. 3. Section of last phalanx. 4. Matrix.

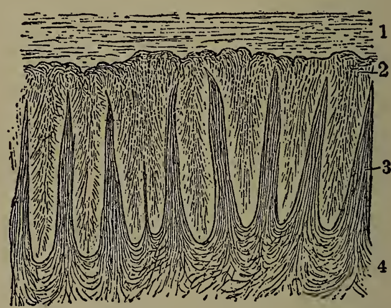
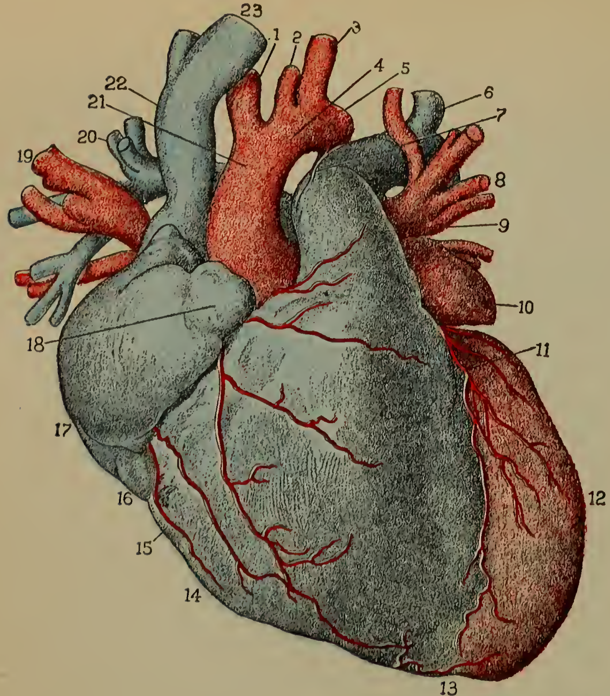


FIG. 146.—MAGNIFIED SECTION THROUGH NAIL.
1. Outer horny layer. 2. Cellular layer. 3. Outer layer of the cuticle layer of the nail. 4. Cuticle.

The teeth are located in the alveolar processes of the in-

[1] The sebaceous secretion contains lanolin (a fat of cholesterin), which, by not becoming rancid, protects the hair and skin.



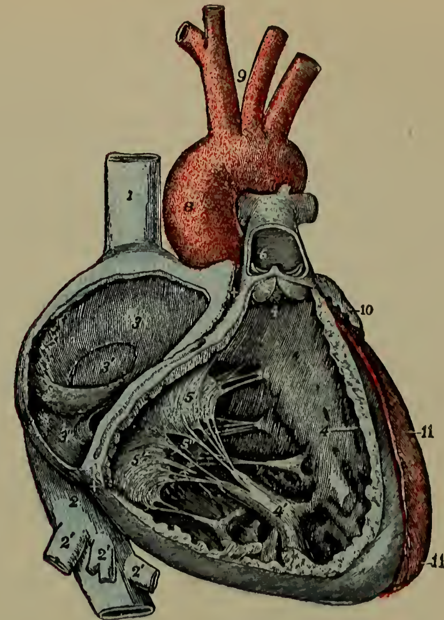


PLATE XIV.

FIG. 129.—THE HEART.

1. Innominate artery. 2. Left carotid artery. 3. Left subclavian vein. 4. Arch of the aorta. 5. Descending aorta. 6. Left pulmonary artery. 7. Ligamentum arteosum. 8. Left pulmonary veins. 9. Pulmonary artery. 10. Left auricle. 11. Left coronary sinus and left coronary artery. 12. Left ventricle. 13. Apex of heart. 14. Right ventricle. 15. Right coronary artery. 16. Coronary sinus. 17. Right atrum. 18. Right auricle. 19. Right pulmonary. 20. Right pulmonary artery. 21. Ascending aorta. 22. Vena cava superior. 23. Right innominate vein.

FIG. 130.—SECTION OF HEART TO SHOW RIGHT AURICLE AND RIGHT VENTRICLE.

1. Superior vena cava. 2. Inferior vena cava. 3. Right auricle. 4. Right ventricle. 5. 5', and 5", Tricuspid valve. 6. Pulmonary artery, and at its entrance the pulmonary semilunar valves. 8. Aorta. 9. The vessels in order from the left are innominate artery, left common carotid, left subclavian. 10. Part of right auricle (appendix auriculæ). 11. Apex. x. Auriculo-ventricular grooves. 3. Tubercle of lower of right ventricle. 3'. Fossa ovalis, and Eustachian valve. 3". Coronary sinus. 4'. Columnæ corneæ. 5". Chordæ tendineæ. 2'. Hepatic veins cut short.

ferior and superior maxillary bones and in the gums, which are a modification of the mucous membrane.

Parts of a Tooth.—A tooth (Fig. 147) consists of the part projecting from the gums, called the *crown;* of a constricted portion, the *neck,* and the part occupying the alveolus, called the *fang,* or root.

Varieties of Teeth.—The teeth (Fig. 95) are of four varieties: the *incisors,* or cutting teeth, the *canines, bicuspids,* and *molars,* or grinders.

The incisors have the crown wedge shaped, convex in form, beveled and slightly concave behind; the fang is single, long, and conical. The canines have conical crowns and conical fangs. They rise above the level of the other teeth. The upper pair are commonly known as the "eye teeth," and the lower as the "stomach teeth." The cuspids have two cusps projecting from the crown and a single fang; they are also called premolars. The molars have a nearly cubical form, with four cusps on the upper molars and five cusps on the lower molars. The first two upper molars usually have three fangs, while the first two lower have two fangs. The third molar is called the "wisdom tooth," on account of its appearing so late. It usually has but one fang, but shows a tendency to form other fangs.

FIG. 147.—VERTICAL SECTION OF A TOOTH.

1 and 2. Crown of tooth. The construction portion, the neck. The lower projections, the roots or fangs. 1. The enamel. 2. The dentine. The outer covering of the roots, the cementum. 3. Tooth cavity and pulp.

Structure of a Tooth.—The body of the tooth is composed of a substance called *dentine,* or *ivory,* which consists of wavy branching tubes, called *dental tubes,* imbedded in a hard intertubular substance; the tubes are about $\frac{1}{4500}$ of an inch in diameter. Dentine is composed of twenty-eight parts of animal matter and seventy-two of mineral matter. The thin crust on the crown is called enamel. It is the densest tissue of the body, has but 3.5 per cent of animal

matter, and is made up of hexagonal rods (*enamel columns*), which are about $\frac{1}{5500}$ of an inch in diameter.

The fang of the tooth has an outer layer of true bone, which covers the fang from the neck down, and is thicker at the apex of the fang. This layer is called the *cementum,* or *crusta petrosa.*

The cavity of the tooth is filled with the *tooth pulp,* which consists of a soft, very vascular connective tissue, with numerous nerves and cells, the latter being of two kinds: the columnar, or *odontoblasts,* arranged in a layer lining the pulp cavity, and the *stellate* and *fusiform,* which permeate the pulp substance.

Dentition.— By dentition[1] is meant the time and manner of appearing of the teeth. With milk teeth this is a very critical time with the child, the appearance (*cutting*) of a tooth producing a great disturbance of the health of the child. The dentition of the permanent teeth produces very little disturbance except that of the "wisdom tooth," which is sometimes very painful, and interferes with the general health.

Nerves of the Teeth.—The nerves and blood vessels of the teeth enter the jaw at an opening called the dental foramen, and enter the teeth by means of openings in the fangs.

Care of the Teeth.—The teeth, properly cared for, will last a long time. If, however, they are subjected to extremes of hot and cold liquids and other substances, the enamel soon becomes broken, making the teeth easy of decay. Particles of food left between the teeth after eating should be removed, and the teeth thoroughly washed with a toothbrush. If the food is not removed, it tends to produce, by decomposition, acids and products which are not only injurious to the teeth, but to the general health as well.

---

[1] The arrangement and number of the teeth are represented by a diagram which shows half of the jaw with initial letter of the teeth; such a formula is called a *dental formula.* For the milk teeth it is $\frac{I.2 - C.1 - M.2}{I.2 - C.1 - M.2}$ making, for the whole number, twenty. For the permanent teeth, $\frac{I.2 - C.1 - B.2 - M.3}{I.2 - C.1 - B.2 - M.3}$ making, for the whole number, thirty-two.

The Necessity for Bathing.— The skin is one of the chief channels for the excretion of waste products. The perspiration contains fatty substances, organic and mineral salts, dead epithelial cells, and water. When the liquid portion of the perspiration evaporates, it leaves the solid substances on the surface of the skin, and with these may collect dust and dirt, and sometimes germs of disease. This layer of impurity may in several ways be injurious to health. 1. It tends to clog the pores of the skin, thus preventing the perspiration, and checking the proper action of the skin, one of the principal organs of excretion. The skin failing to do its duty, additional work is thrown upon other organs, chiefly the kidneys and lungs. This extra work will in time exhaust the overtaxed organs, and bring about serious diseases. 2. This layer of material on the surface forms a favorable condition for the development of bacteria, and many skin diseases may result from such neglect. 3. This unwholesome layer favors parasitic skin diseases. 4. When the skin cannot perform its proper function, the individual is more liable to take cold. We should be as careful about the cleanliness of our person as we are about the food we eat or the clothes we wear.

Aside from cleanliness, bathing has a marked effect upon the general system, which will vary with the kind of bath. Its general effects are as follows: *a.* The cold bath, which may range in temperature from 0° C. to 15°C. Its effects are to cool the blood in the cutaneous vessels; stimulate the heart and respiration; raise the blood pressure by temporarily overfilling the internal blood vessels. It is useful as a refrigerant in fever; refreshing to the strong and to those in good health; may be used as the morning bath. *b.* The cool bath, which has a temperature from 15° C. to 22° C., has a similar effect to the cold bath, but less marked. It may be used by persons weaker than those who take the cold bath. *c.* The tepid bath ranges in temperature from 29° C. to 34° C., acts both chemically and physically as a cleansing agent; soothes the nerves. Its chief uses are for ordinary personal

cleanliness; to allay the restlessness of fever, and to lower temperature, and as a sedative when one is nervous and exhausted by overwork. This may be used as the evening bath, and by the most delicate. *d.* The warm bath should have a temperature of 34° C. to 38° C. Its general action is to raise local temperature and circulation, stimulate glands, soothe the nerves to the corresponding centers, produce perspiration in fevers, and act as an anodyne and antispasmodic. This bath may be used by any one. *e.* The hot bath has a temperature from 38° C. to 41° C. Its effects are similar to those of the warm bath, but more powerful. When applied locally, it attracts the blood to the part bathed and from distant parts. We have seen in the study of circulation why it is used to relieve internal congestion, as in colds, etc.

The benefit of the bath depends much upon the time and manner in which it is taken. The bath should not be taken just before, nor immediately after, a meal. The cold bath should not be used when the body is greatly exhausted by severe mental or muscular exercise. A bath is more beneficial in the forenoon than in the afternoon.

Cold baths should not be taken when the person is chilly, perspiring, or by persons in a weak condition. The bath should be taken briskly, the skin well rubbed and quickly dried. Exercise should follow most baths. If the mind is brighter, and the skin has a healthy glow, and exhilaration follows, the bath has been beneficial; but if languor follows, the skin is blue to pale, and there is a sensation of chilliness, then it has been injurious, and reaction should at once be brought about by vigorous rubbing or by exercise.

Hot baths have a relaxing influence on persons of weak hearts or suffering debility, and they may faint while taking them. Persons suffering from heart disease or chronic disease of any important organ should not take frequent cold baths.

Outdoor bathing should not be taken for an hour or two after a full meal, nor just before a meal, especially before breakfast.

Salt water is more stimulating to the skin than fresh water. To those in health it is refreshing and invigorating, but the bather should come out of the water as soon as there is the slightest feeling of chilliness. Too frequent bathing may prove more injurious than beneficial. It should not be engaged in more than once a day, except by the very vigorous.

Care of the Hair and Nails.— The hair should be frequently washed, but the use of much soap may prove injurious by destroying the natural secretion of the oil of the hair, making the scalp dry and hard. The hair should be brushed with care, as brushing it too long or too hard may stimulate the scalp, causing an increase of the scurf. A similar result may be produced by using too stiff a brush. Hair dyes and hair oils should not be used, as in most cases they contain substances which are not only injurious to the hair but also to the health.

The nails should be kept of proper length. When not kept clean, they become not only unsightly, but may serve as carriers of disease germs. Sores and wounds should never be picked with the nails. If they are permitted to grow too long, they are liable to be broken off, which not only injures their appearance, but their texture as well.

They should be kept of the proper length by filing, rather than by cutting, and never by biting them off. In removing dirt from beneath the nails, hard instruments should never be used, but a toothpick or an ivory cleaner. In no case should the nails be trimmed to the quick, or their surfaces scraped. The latter tends to make the nails thick and rough. They should be cleansed with a nail brush, which will not injure the smooth and polished surface.

How Alcohol Affects the Skin.— When strong alcohol is applied to the epidermis, it tends to harden it. Bathing the skin with alcohol in case of protracted disease prevents bed sores by hardening the outer surface of the epidermis. It tends also to stimulate the skin; this is seen by the redness of the skin when bathed in strong alcohol. Taken

internally, it has marked effect on the skin, congesting its blood vessels. This condition, if the drinking becomes habitual, becomes chronic, and may bring about a disordered condition of the skin and modification of the activity of the glands. The soft, satiny feeling in the skin is one of the first evidences that the person is drinking to excess, and a warning of the more serious evils to follow.

Later on, the skin becomes thick and discolored, sometimes red, and in some cases sallow; in this condition it becomes liable to various diseases. At first the cheek and nose have a healthy glow of red, but later on they become more congested, and a purple takes the place of the red, showing by the increased size of the vessels a chronic congestion of the blood vessels, as well as a diseased condition of the blood.

CHAPTER XIV.

THE KIDNEYS.

EXPERIMENTS AND DEMONSTRATIONS.

1. Get from the butcher the kidneys and bladder of the hog or sheep (do not cut the kidney loose from the connection with the bladder). Notice,

a. Relation of Kidneys to the Bladder.— Where do the tubes (*ureters*) from the kidneys to the bladder enter it? Do you see any advantage in this arrangement?

b. The Position of the Fat.— Do you see any reason for this large amount of fat?

c. The Cap-shaped Body (*Suprarenal Capsule*) *Covering the Upper Part of the Kidney.*— Does it have any duct? Has it any connection with the kidney? Make several sections of the capsule, put them into sixty-per-cent alcohol, and make permanent mountings, as directed in the Appendix.

d. The Form, Size, and General Appearance of the Kidneys.— How do the blood vessels enter the kidney?

e. The Large Artery (*Renal*) *Entering the Kidney.*— Prepare an injective mass as directed for the veins under subject of circulation, but in place of the chrome yellow use carmine, which should be added while the gelatin is hot and thoroughly stirred to secure complete mixing. Tie the free portion of the renal artery securely to a canula of convenient size, and inject the arteries as directed under circulation.

f. The Large Vein Entering the Kidney.— Prepare an injection as directed in *e*, but use in place of carmine, chrome yellow (see Circulation). Inject the veins with this mass.

Cut the injected kidney loose from the ureter, one or two inches from where it enters the bladder. When the injection mass is well set, make a section of the kidney so as to divide it into halves flat-wise (Fig. 148), and then determine the structure of the kidney. Examine the different portions of one of the halves of the injected kidney with the dissection microscope. Make thin sections of the cortical and medul-

lary portions; mount in glycerin, and examine with a two-thirds or three-fourths objective.

2. Make permanent mounts of different parts of the uninjected kidney, especially of the cortical portion, the medullary portion, a pyramid, the mucous membrane of the pelvis. Examine with two-thirds and one-fourth objectives.

3. Prepare a permanent mount of longitudinal and cross-section of the ureter. Examine under high and low power objectives.

4. Tie the free end of the portion of the ureters connected with the bladder, and inflate the bladder by blowing through a glass tube securely fastened in the large exit tube (*urethra*) of the bladder; and when inflated, tie the urethra so that the bladder will remain inflated. Compare the capacity of the bladder with the total capacity of kidneys. What does this indicate in regard to the constancy of the secretion of the urine? What evidence do you see of muscular tissue? of elastic tissue? of inelastic tissue?

5. Examine the entrance of the ureters into the bladder. Is there any means to prevent the reflow of the urine back into the ureters when the urine is being expelled from the bladder?

6. Verify your conclusion made in regard to the structure of the bladder by examining both teased specimens and sections of the bladder.

7. Examine longitudinal and cross-sections of the urethra.

Compare your observation with the statements given in the text.

THE KIDNEYS.—TEXT.

As has been stated, the three most important waste products of the body resulting from its complex metabolism are carbon dioxide, urea, and water.

The lungs provide for the elimination of the greater part of the carbon dioxide and of some of the water; the skin, for some of the water, a small per cent of the carbon dioxide, and a small amount of urea. The principal waste product resulting from the nitrogen metabolism is urea. For its excretion there is provided a special apparatus consisting of the kidneys, the ureter, bladder, and urethra.

Where and how urea is formed we are still in doubt. There are many reasons for believing that it is not secreted by the kidneys, as was formerly supposed. If we are to believe recent experiments and investigation, the liver is the chief organ concerned with the secretion of urea, and the kidneys with its excretion or elimination.

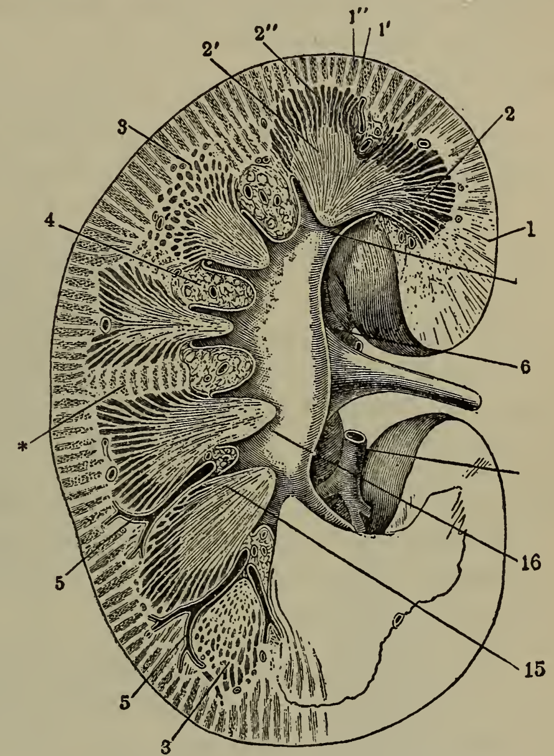


Fig. 148. — Longitudinal Section of the Kidney.
1′. Medullary rays. 1″. Labyrinth. 1. Cortex. 2. Medulla. 2′. Papillary portion of medulla. 2″. Boundary layer of medulla. 3. Tranverse section of tubules in boundary layer. 4. Fat of renal sinus. * Tranversely crossing medullary rays. 5. Artery. 6. Renal artery entering at hilum. 7. Renal calyx. 8. Ureter. 15. Pyramid. 16. Pelvis.

Structure of the Kidneys. — The two kidneys are situated in the posterior part of the abdominal cavity, behind the peritoneum and intestine, close to the spinal column, one being on each side, on a level with what is called the waist, or loins (Fig. 6). The kidneys are surrounded by a mass of fat and loose areolar tissue, having its upper portion capped by a body called the suprarenal capsule. They are of a dark brown color, of characteristic shape, resembling that of the lima bean, but much thicker in proportion. Their weight varies from four to six ounces.

They are covered by a dense, tough fibrous capsule, being connected to the substance of the kidney by fine processes of connective tissue and minute blood vessels, from which it can be easily removed. Their internal surface is concaved, forming a deep longitudinal fissure, the *hilum* allowing the passage of the blood vessels, nerves, and ureter into and out of the organ.

A vertical section of the kidney presents for study the outer deep red portion, the *cortical,* and the inner pale red portion, the *medullary,* or pyramidal portion, entering into the composition of which are twelve papillæ, or pyramids, whose apices project into a funnel-shaped cavity called the *pelvis,* formed by the dilation of the excretory duct, the *ureter,* which is divided into several truncated branches or infundibula, called *calices,* around the apices of the pyramids. The cortical substance also invests the bases of the pyramids, sending off between them what are known as the *columns of Bertin.* In texture the cortical substance is soft and friable, and under lower power shows small granules, due to the Malpighian corpuscles.

The medullary portion consists of two layers, the outer, or boundary, layer, and the papillary part, denser than the cortex, and presenting striæ, or radial streaks, passing into the cortex, and there called medullary rays, or *pyramids of Ferrein.* The portion of the cortex lying between the medullary rays is called the labyrinth, in which is found the granular bodies, the *Malpighian bodies.* By examining the apices of the pyramids with a low-power lens, small openings will be found, through which the urine exudes into the calices of the pelvis of the kidneys.

Microscopic Structure.— On microscopic examination the kidney is found to be very complex in structure. It is made up of blood vessels, tubules, bound together by a small amount of connective tissue. The kidney is, in fact, a compound tubular gland, the unit of which is the *tubuli uriniferi* (Fig. 149, B), or tubes which carry the urine. They arise in the cortex by a cup-shaped expansion, the Malpighian capsule,

afterward pursuing a complicated course, and uniting with other tubes to form collecting tubes which discharge their contents into the calices by small openings at the end of the pyramids. The uriniferous tubules are found in both cortex and medullary portions, being for the most part contorted tubes in the cortex, and straight tubes in the medullary portion. The Mal-

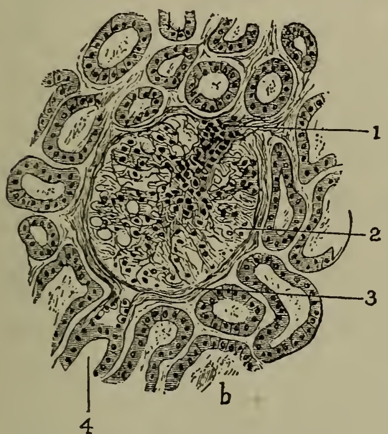


FIG. 149. B.—MALPIGHIAN BODY.

1. Vessels coming to glomerule (vas afferens) and vessels going from glomerule (vas efferens). 2. Glomerule. 3. Capsule of glomerule. 4. Contorted tubule.

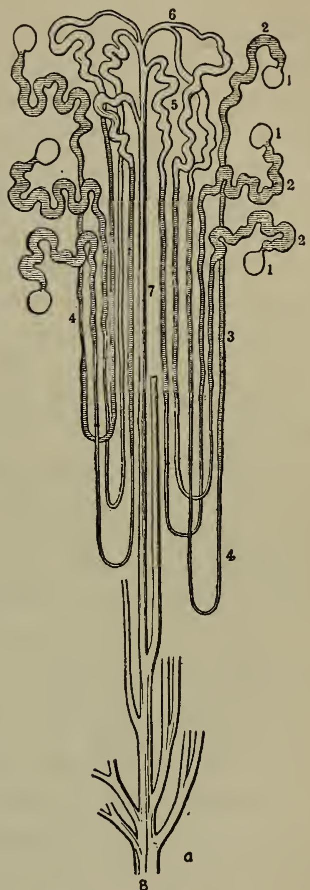


FIG. 149. A.—DIAGRAM OF STRUCTURE OF KIDNEY.

1. Malpighian body. 2. First convoluted tubule. 3. Henle's loop. 4. Secondary convoluted tubule. 5. An ascending loop. 6. Collecting tubule. 7. Collecting tubule joining with collaterals. 8. Excretory duct (duct of Bellini opening into apex of the papilla).

pighian body from which the tubules arise are about one one-hundred-and-twentieth inch in diameter, each capsule inclosing a bunch of convoluted blood capillaries called a *glomerulus* (Fig. 149 B). The tubule consists of a layer of epithelial cells resting on a basement membrane, the blood vessels being brought into close connection by an arrangement soon to be described.

The tubule leaves the capsule by a narrow neck, which soon becomes twisted on itself to form the first convoluted tubule, which straightens somewhat to form the spiral tubule, then passing straight downward becomes smaller, and passes into the medullary portion to form the descending *loop of Henle.* Before reaching the apex of the pyramid, the tubule turns and forms the loop of Henle, and, moving upward in a direction parallel to the descending loop, forms the ascending loop of Henle; it again enters the cortex, forming the zigzag tubule; becomes more contorted, forming the second convoluted tubule, joining a straight or collecting tubule, which passes through the medullary portion, and unites with other collecting tubules to form an excretory duct (*duct of Bellini*) that opens into the apex of the pyramid, through which the secreted urine may pass into the pelvis of the kidney.

The different parts of the tubule differ very much in the kind of the epithelium lining them. In the epithelium we recognize three varieties: (1) granular cubical cells, having a fibrillated or rodded structure, as in the first convoluted tubule, spiral tubule, ascending loop of Henle, zigzag tubule, and second convoluted tubule; (2) clear cubical in the descending loop of Henle, and straight collecting tubule; (3) in the capsule squamous epithelium reflected over the glomerulus, there being thus two layers, the inner of which is fused with the glomerular loop.

It is believed that the cells of the convoluted and irregular parts of the tubules are secreting in their function; as they exhibit the character of active secretive cells, they are therefore probably concerned with the extraction from the blood of the chief organic substances of the urine. The cells of the collecting and discharging parts of the tubule are like those seen in the conducting portion of other glands, and probably have no secreting function.

The kidney is a highly vascular organ. The renal artery enters it as a direct branch from the aorta, entering the kidney at the hilum, dividing on entering the pelvis into several

pyramids in the columns of Bertin. When they reach the boundary between the cortical and medullary portion, these branches spread laterally from incomplete anastomosing arches at the bases of the pyramids; from these arches some branches proceed outward toward the cortex and inward to the medullary pyramids. The vessels in the cortex between the medullary rays are called the *interlobular arteries.* The arteries in their outward course give off lateral branches that form the afferent vessels of the Malpighian bodies, forming the glomerulus (Fig. 149). From each granular tuft somewhat smaller efferent vessels pass out of the capsule, and again break up into a network of capillary vessels over and between the tubules. Note here the double capillary network somewhat resembling that of the liver. The arterial branches which go to the medullary substance in a straight direction through the pyramids are called the *arteriæ rectæ,* and these break up into a plexus of capillaries with elongated meshes from which the *venæ rectæ* are given off, which form into venous arches, corresponding to the arterial arches at the boundary of the cortex and medulla. The capillaries from the Malpighian bodies unite to form the interlobular veins, which empty into the venous arches.

The small veins at the surface of the cortex are arranged in a star-shaped manner, and are called the *venæ stellatæ.* The lymphatics of the kidneys arise in the lymph spaces of the connective tissue of the organ, and form into vessels which leave the kidney at the tubes or through the capsule. The nerves of the kidney are derived from the renal plexus and lesser splanchnic nerves, and form small trunks with ganglia.

The Urine. — Fresh urine is of a clear straw color, of a peculiar odor, and an acid reaction. It consists of water holding in solution urea and other solids, and has a normal specific gravity of 1.02 on the average, but is subject to variation from this average within certain limits, the specific gravity corresponding to the proportion of the solids to that of the water; thus it may range from 1.002 after drinking

much water, to 1.040 after abstinence from drinking fluids, or after copious perspiration. Any cause that tends to remove large quantities of water from the body through other channels than that of the kidney, as through the skin, the lungs, or bowels, lessens the proportion of water in the urine and increases its specific gravity, as the amount of solids discharged from the kidney remains, in normal condition, quite constant. The activity of the epithelium of the tubules will also influence the specific gravity by increasing or lessening the proportion of water.

Climatic conditions have a marked influence, as when it is cold and the amount of perspiration is scanty, the amount of urine is increased, as well as being more diluted than when the perspiration is copious. From this it will be easily seen why *persons inclined to kidney troubles or suffering from them should seek warm climates,* or *at least keep the body well clothed and the skin active.*

In the adult, the normal average amount of secretion daily is about fifty fluid ounces, or two and one-half pints. The percentage composition is as follows: Water, 96.7; solids, 33, of which the more important are urea,[1] 14.2; uric acid and other nitrogenous substances, 10.63; salts, 8.13, the more important of which are sulphates, phosphates, chlorides of sodium and postassium, and occasionally lactates, oxalates, hippurates, and acetates.

The acidity of the urine is not due to the presence of free acid, but to acid-sodium phosphates. On standing in contact with the air, the urine becomes alkaline, due to the conversion of urea into ammonium carbonate, the decomposition being due to the presence of micro-organisms. The color of the urine is due to certain pigments of whose nature we are in doubt, but by some physiologists the chief coloring matter is considered to be urobilin, which is probably derived from the bile pigments.

---

[1] The urea contains from 83 to 86 per cent of the nitrogen of the urine; ammonia from 3 to 4 per cent, and uric acid and kreatin, xanthin, etc., the remainder of the nitrogen.

Urea, one of the most important constituents of the urine, is the chief end-product of proteid metabolism. Its production is much more complex than the formation of carbon dioxide or water.

Excretion of the Urine. — The excretion of the urine is now generally thought to consist of two or more distinct processes: (1) *of filtration,* by which water and the ready-formed salts are taken from the blood by the action of the Malpighian corpuscles by the renal glomeruli; (2) *of true secretion,* which takes place in the tubuli uriniferi, which separate from the blood the urea and like substances.

Passage of the Urine into the Bladder.— There are three influences which work together to effect the passage of the urine from the kidney: (1) gravity, (2) the high pressure under which it is secreted, (3) the rhythmical peristaltic contraction of the ureters.

The Ureters. — The ureters are the tubes which lead from the kidney to the bladder, one entering on each side, near the base of the bladder (Fig. 6). They are from sixteen to eighteen inches long, and about the diameter of a goosequill. They are composed of an outer fibrous coat of connective tissue containing blood vessels and nerves, a middle muscular coat of longitudinal and circular unstriped fibers, and an inner mucous coat made up of several layers of stratified transitional epithelium. The ureters enter the bladder obliquely so as to form a sort of valve to prevent the reflux of the urine from the bladder.

The Bladder and the Urethra.—The organ for the retention of the urine until excreted from the body is the bladder. It is situated in the pelvic cavity, and has an average capacity of twenty fluid ounces. Its structure resembles the ureters, but it has thicker mucous and muscular coats.

From the neck, or narrow end of the bladder, there passes a tube (the *urethra*) by which the urine is expelled from the body. At its beginning the circular nonstriated muscular fibers become thicker, but the opening is closed by a sphincter muscle (*sphincter urethræ*), of striped muscle fibers, which

by its tonic contraction keeps the opening closed, and by its relaxation permits the urine to pass into the urethra.

The expulsion of the urine is produced by the gradual accumulation of the urine, producing a tension in the organ, bringing about a contraction of the muscular walls and a relaxation of the sphincter. In young children the whole act is reflex. As age advances, there is acquired more or less control of the act; the will may send a stimulus which inhibits the reflex movement and assists the sphincter, preventing expulsion, or it may inhibit the sphincter, and by stimulus to the abdominal muscles, aid in the expulsion.

Conditions Affecting the Secretion of the Urine. — The more important conditions affecting the secretion of the urine are: —

1. The blood pressure. The more blood in the renal artery, the greater its secretion. This increased pressure may arise (*a*) from an increase in the force or frequency of the heart beat; (*b*) from a dilation of the blood vessels of the kidneys through the action of the vasomotor nerves; and (*c*) by constriction of the small arteries of other areas, as that of the skin.

2. By the nervous system independent of the action of the vasomotor nerves. We know little as to how this is effected.

3. By certain substances (*diuretics*), as water, sodium chloride, sodium and potassium nitrate, caffein, grape sugar, digitalis (foxglove), and alcohol.

Effect of Alcohol on the Kidneys.— As alcohol increases the force and frequency of the heart beat, and as it also causes a dilation of the blood vessels through its action on the vasomotor nerves, it will be readily seen why its habitual use will prove very injurious to the kidneys, resulting, by its continued disturbance (congestion) of the renal circulation, in albuminuria [1] and Bright's disease.

---

[1] High living or an excessive use of iced tea or ice-water may produce albuminuria. *Colds are one of the most fruitful sources of acute Bright's disease.* Formerly Bright's disease was used as a synonym of albuminuria, but this is not a correct use of the term, as this is a different disease. While albumin is in excess in Bright's disease, Bright's disease does not accompany albuminuria.

CHAPTER XV.

DUCTLESS GLANDS.

EXPERIMENTS AND DEMONSTRATIONS.

1. Remove the muscles from the neck of a rabbit or a cat, and watch carefully for a glandular organ (the *thyroid gland*), reaching from the thyroid cartilage down the sides of the trachea, the lateral masses being connected by a narrow strip of glandular substance. Look carefully for similar masses (*accessory thyroids*), distributed in various parts of the neck, and even as low down as the heart. Do you find in any of these glands any evidence of a duct? Make a section of different portions, and examine under low power (twenty or thirty diameters), and carefully note general structure. Make permanent mounts of different portions as directed in Appendix. Examine under two-thirds and one-sixth objectives. What evidence do you see that the gland has a secretion?

2. Examine the cap-shaped body (*suprarenal capsule*) on the upper part of the kidney. Does it have any connection with the kidney? Has it any duct? Determine its microscopic structure. What evidence have you that it has a secretion?

3. Remove the brain from its cavity, and take special care not to injure the lower portion in the region of the sphenoid bone. Note this part of the brain, and look for a reddish gray body (*pituitary body*) covered by the folds of the pia mater. Of how many lobes does it consist? Do these lobes differ in structure? Examine under both high and low powers. Is the body vascular?

4. In a brain that has been hardened in alcohol or synthol find the pineal gland, and study its relations and structure. What evidence do you find that it is the vestige of a once functional organ?

5. Examine the spleen, and determine its relation, blood supply, and microscopic structure. Has it any resemblance to a lymphoid gland? Does it have the structure of a secreting gland?

DUCTLESS GLANDS.— TEXT.

Importance.— Until recent years, these glands were looked upon as the remnants of once functional glands, now playing no important part in the work of the adult organism, and therefore of little importance. The fact that the removal of these organs produces a great disturbance in the healthy action of the body, and in some cases causes death, has given a new interest to their study, and has resulted in the discovery of some very important physiological facts. While we are still in doubt as to their full importance, it is well established that most of them are more than mere rudiments of organs, and, while they have no secretions to give off, most of them have *internal* secretions which have very important functions. To this group of glands belong the *suprarenal capsule,* the *thyroid gland, thymus gland,* the *pituitary body,* the *pineal gland, coccygeal glands, carotid glands,* and *spleen.* While the liver and the pancreas are not ductless glands, they are related to them by virtue of their internal secretions, and need mention in this connection.

Internal Secretion.— In most of these glands the parenchyma cells are morphologically of the secretory type, and as active constituents have been extracted from them, we are safe in assuming that they produce a secretion. As they have no ducts, these secretions, whatever their nature or quantity, pass directly into the blood (as in the suprarenal capsule), or indirectly into the blood by means of lymphatics (as in the thyroid), and as they do not pass to a free surface by means of a duct, as in the salivary and other glands, their secretion is called *internal secretion.*

Thymus Gland.— When at its full development, it is a long, narrow body situated in the front of the chest, behind the sternum, and reaching upward to the lower part of the neck. It has well-marked lobes, and is of a reddish or grayish color. It has a fibrous capsule, which sends off numerous processes, which divide the gland into numerous lobes, and a well-marked cortex and medullary portion; and it contains

a large amount of adenoid tissue, with numerous lymphoid corpuscles in the cortex.

After the second year it begins to diminish, and by adult age there is only a small vestige remaining, and it may, therefore, be looked upon as a rudimentary organ. It gives numerous extractives.

It is supposed to be the "parent source from which all the red corpuscles are derived," and hence its large size in the young child. It is thought that the first red corpuscles are developed from the thymus gland, and from these the others are formed.

Thyroid Gland.— It is situated in the neck. It is made up of two lobes which lie on both sides of the trachea, reaching upward to the thyroid cartilage and connected in front by a smaller middle lobe. It is a very vascular organ, and of variable size in different individuals. It is covered by a dense capsule of areolar tissue, which sends off branches inclosing vesicles containing colloid material, the vesicles being lined by a single layer of short cylindrical or cubical cells.

The colloid substance of the vesicles is believed to be the secretion of these glands. This secretion finally ruptures the vesicles containing it, and finds its way to the lymph, and by the lymph to the blood.

The complete removal of the thyroid gland in some animals produces death. In man its removal produces a disease called mucous dropsy (*myxœdema*). The disease is cured by the injection of the extract of the secretion from the thyroid of the sheep.

The Suprarenal Capsules.—These are two cap-shaped bodies (Fig. 6) situated on the super and outer part of the kidney. They are invested by a capsule of connective tissue, which sends off very fine prolongations into the substance of the gland. The gland is made up of medullary and cortical portions. The gland is richly supplied with nerves. The fibers enter through the hilum of the gland, but the method of the termination has not been determined. If one gland is removed, the other increases in size (*hypertrophies*).

The results from experiments with the gland seem to indicate that the gland is essential to life; and its destruction by disease produces symptoms similar to those of Addison's disease. The giving of suprarenal extractive in such cases has proved beneficial.

Internal Secretion of the Pancreas.—Within a few hours after the tôtal removal of the pancreas, sugar makes its appearance in the urine, reaching as high as ten per cent, and death generally follows in fifteen days or less. If portions of the gland be left (at least one tenth), sugar only appears in the urine when carbohydrates are eaten, but not otherwise. This effect is not due to the normal secretion of the pancreatic juice, as this may be entirely removed without producing the effects described. The existence of an internal secretion has not been established, and we do not know the cause of the injurious effect of removal of the organ. Its power to prevent the formation of sugar is, however, established.

The Spleen.—The spleen (Fig. 126) is a ductless organ, and the largest of the vascular organs, but it has probably no internal secretion. The functions of the spleen have been given under the subject of alimentation. The spleen may be removed without any marked injurious effects.

The Pituitary Body.—This small, reddish-gray body lies in a depression (*sella turcica*) of the sphenoid bone. It consists of a small posterior lobe of nervous tissue and an anterior larger lobe of tissue resembling the thyroid gland. These two lobes are not only histologically different, but are also embryologically distinct.

The function of the organ is not known. By some its function is thought to be similar to that of the thyroid gland. In case of disease of this organ there has come to be associated with it a disease (*acromegaly*) in which there is an abnormal increase in the size of the extremities of the bones.

The Pineal Gland.—This gland is situated beneath the back part of the corpus callosum, and rests upon the corpora quadrigemina. It is a small body of reddish color.

It has a central cavity lined with ciliated cells. Its glandular substance is made up of an outer cortical substance resembling in structure the outer lobe of the pituitary body, and an inner central layer of nervous substance. The pineal gland is considered as a purely vestigial structure, being an atrophied third eye and without any important function in the human subject. It is of morphological interest to the scientist in that it is a good example of the principle that organs, when they cease to be functional, become reduced in size and structure.

The Carotid Glands.— These are situated at the branching of the common carotid artery, on each side. They are composed of a plexus of small arteries, inclosed and supported by a covering of connective tissue, in which there are numerous connective tissue corpuscles. Surrounding the blood vessels are one or more layers of cells, resembling secreting cells, probably derived from the plasma cells of the connective tissue.

The Coccygeal Glands.—These are situated in front of the tip of the coccyx. They have the same structure as the carotid glands. The function of these glands is not known.

CHAPTER XVI.

GENERAL AND SPECIAL SENSES.

EXPERIMENTS AND DEMONSTRATIONS.

1. To determine the cold spots on the arm. Take a sharp pointed piece of ice, and touch different parts of the bare arm. What parts are the most sensitive?

2. Determine the hot spots of the arm by touching different parts with a pointed copper instrument dipped in hot water. Do the hot areas agree with those of the cold areas?

3. Determine which gives the clearer sensation, light pressure or heavy pressure.

4. Test, by means of a blunt pointed compass, various parts of the body as to which is the most sensitive to touch. Place the compass points together, then gradually separate them until you can distinguish the two points. Which parts of the body are the more sensitive?

5. Place two light weights, one cold and the other warm, on corresponding fingers of the hand. Which is the heavier?

6. Place the hands in cold water, then in tepid water, then in warm water. Reverse the process. What difference do you note? Is our sense of temperature absolute or relative?

7. Cross the middle finger over the index finger; roll a small marble between the tips. How many marbles do you seem to feel? Cross the fingers in the same way, and rub the point of the nose. How many noses do you seem to feel?

8. Put a drop of vinegar on a friend's tongue, and, with a reading glass, notice how the papillæ of the tongue start up.

9. Rub different parts of the tongue with a piece of gum-aloes. What parts seem to be most sensitive to bitter? Try the same with a piece of salt, and determine what parts are most sensitive to saline substances.

10. Try the sensitiveness of the tongue with sweet substances and with sour substances. How do the dorsum of the tongue and the edges compare in sensitiveness?

11. Rub the tongue with the pulp of a ripe apple, and close the nostrils. Does it affect the taste when the nostrils are closed? Rub the tongue with a piece of onion, keeping the nostrils closed. Close the eyes, and try the experiment. Can you tell the apple from the onion? What does this teach you in regard to flavor? To what is the taste of coffee most due?

12. Taste various substances with the eyes closed. Explain the difference.

13. Place pieces of zinc on the tongue, also beneath and above the tongue, and have their ends brought into contact; an acid taste is produced due to the feeble galvanic currents.

PAIN AND COMMON SENSATION.— TEXT.

Common sensation, or general sensibility, seems to arise from a number of obscure sensory impulses proceeding from the skin and other parts of the body, and by these sensations we have a more or less perfect knowledge of our general condition. If these impulses become intense, the sensation is called pain, so we may consider pain as an excessive stimulation of the nerves of common sensation; but pain is not restricted to the nerves of general sensation, for excessive stimulation of any sensory nerve produces pain. Since every kind of overstimulation — mechanical, thermal, chemical, or electrical — may excite pain on the surface of the body, pain may be considered as a cutaneous sensation. It is, however, found in almost all other organs. A slight inflammation makes an organ keenly sensitive to pain. Pain may be caused by the stimulation of a sensory nerve along any part of its course, but the sensation is referred to the nerve termination.

Pains vary in intensity and quality with the nature and strength of the stimulus and the excitability of the nerve affected. If very violent, the sensation seems to be diffused and scattered, so that localization is difficult. The sensations of common sensibility and pain are distinct from other sensations. In the common sensory nerves there is probably no special nerve ending, while in those of special senses each sense has its special end organ.

There are three views held by physiologists in regard to pain: (1) that it is a special sensation provided with a special conducting apparatus in each part of the body; (2) that it is produced by an overstimulation of the special nerves concerned with touch or temperature, or of the other nerves of special sense; or (3) that it is an overstimulation of the nerve of common sensation which tells us both of the surface and internal organs of our bodies.

While there seems to be evidence for each of these views, the evidence leads us to doubt the existence of special end organs for common sensation.

We have learned that through the skin we may experience three classes of sensation: those of touch, of temperature, and of common sensibility, any of which may become painful by undue excitement.

The question arises as to how these different sensations are produced[1]; i. e., are they produced by the difference in the quality of the stimulation, or by the difference in the nerve endings capable of taking notice of these specific qualities?

From what has been learned from experiments and clinic experience, it appears that the skin has four kinds of nerve fibers for the four functions: pressure, heat, cold, common sensibility or pain. Whether each of these fibers has distinct terminal endings has not been determined, and the degree to which each is differentiated is also in doubt.

---

[1] There is little doubt that the sensory nerve trunks contain functionally different nerve fibers. The following are some of the evidences supporting this view: (1) In some diseases of the nerves, touch in certain parts of the skin has been lost, while the power to determine temperature remains, and vice versa. (2) In other cases, common sensibility and pain have been lost over certain areas, while touch has remained; and, in general, it may be stated that one or another class of cutaneous sensations may be lost while others remain. (3) The conducting fibers for these sensations take, to a great extent, different paths in the spinal cord, and have different central endings. (4) From the varied power of the skin, the appreciated various degrees and varieties of tactile sense would seem to indicate that these different fibers have distinct functions. (5) That the hot spots do not coincide with the cold spots would seem to show that there are portions of the skin which have nerves that are sensitive to cold and not to heat, and also the converse seems to imply that there are special nerve fibers for the different temperature sensations.

Organs of Touch.— The sense of touch is not confined to particular parts of the body as are the other senses, but all parts capable of perceiving the presence of a stimulus by ordinary sensation are, in a certain degree, the seat of this sense. We should not, however, consider touch a mere modification of common sensation or sensibility. All parts of the body supplied with sensory nerves are thus in some degree organs of touch, but the sense is exercised in its perfection only in those parts provided with abundant papillæ, and in which the mucous membrane or skin is very thin, as in the tongue and the lips. The teeth and nails each possess a peculiar and acute sense of touch. The hair may also be reckoned an organ of touch, as in case of the eyelashes.

Cutaneous sensations are of various kinds: (1) those of tactile sensation, or touch proper; (2) thermal sensations, or sensations of heat and cold, and (3) sensation of pain. Before considering this matter at length, let us notice the kinds of end organs concerned in the sense of touch.

End Organs. — These are of four kinds: —

1. *Free Nerve Endings.*— In all parts of the epidermis and in the cornea fine nerve fibrils are found derived from the splitting up of the axis-cylinder of a single nerve passing upward from the underlying dermis, the free ends of whose fibrils are sometimes provided with small swellings. Similar enlargements are found in the endings of the nonmedullated nerve fibrils in some parts of the body, and these are sometimes called touch cells.

2. *Tactile Corpuscles.*— These are small, oval bodies (Fig. 150) averaging one three-hundredth of an inch in length, and one five-hundredth of an inch in breadth, situated in the papillæ of the dermis. They are sometimes called the touch corpuscles of Wagner. They are most numerous in the palms of the hands, the soles of the feet, and especially in the fingers and toes; they are less numerous on the back of the hand, lips, and tongue, and are very few on the under surface of the arm and eyelids.

In a large portion of the skin they are absent. Each

touch corpuscle consists of an outer covering of connective tissue arranged in transverse layers, within which is the core, showing elongated nuclei. Passing to the lower part of the core are one or more nonmedullated fibers which wind around it two or three times, and losing the sheath the fibers enter the interior of the corpuscle, the axis-cylinder ending in a small enlargement.

3. *End Bulbs.*—These are also called *organs of Krause.* They are small oblong or rounded corpuscles from one three hundred and sixtieth to one one hundred and seventieth of an inch long. The axis-cylinder of the nerve fiber passes into the interior of the corpuscles, and terminates in a coiled mass or in a bulbous extremity. It is invested by a capsule of connective tissue, with a core of granulated material and nerve sheath of Henle, with the neurilemma appearing to become continuous with capsule. They are only found in the conjunctiva of the eyes, in the mucous membrane of the lips, in the tendons, and in some other parts of the body.

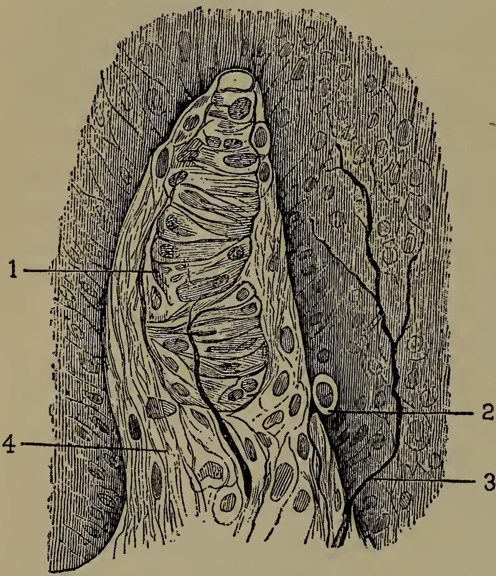


FIG. 150.—TACTILE CORPUSCLE.
1. Tactile corpuscle. 2. A touch cell. 3. Nerve ending in epidermis. 4. Simple papilla.

4. *Pacinian Corpuscles.*—The Pacinian bodies, or the *corpuscles of Vater,* as they are sometimes called, are small elongated oval bodies found on some of the cerebrospinal and sympathetic nerves, especially in the cutaneous nerves of the hands and feet, on branches of the large sympathetic

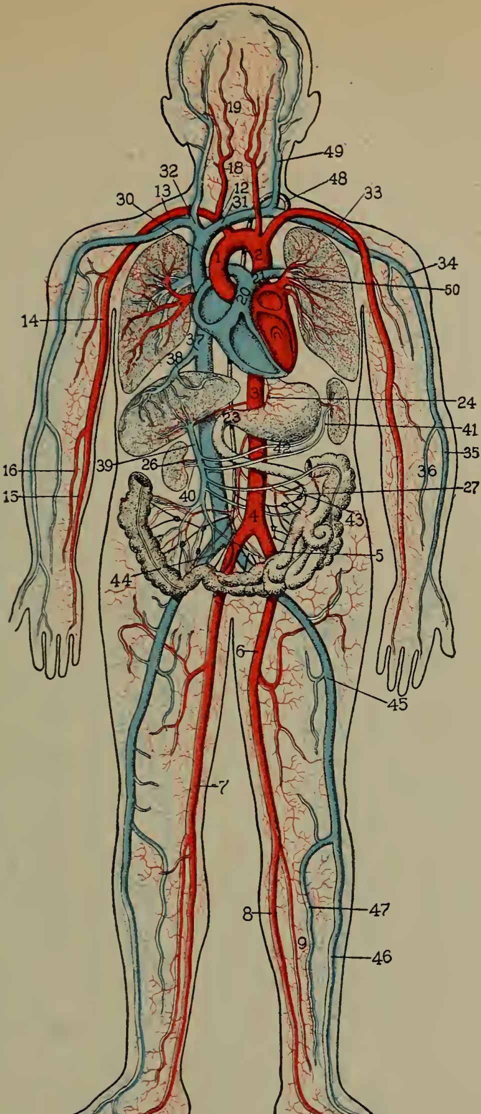


PLATE XV.

FIG. 131.—ARTERIES.

1. Aorta. 2. Descending aorta. 3. Cœliac axis. 24 Gastric artery. 25. Splenic artery. 23 Hepatic artery. 26. Renal artery. 27. Mesenteric artery. 4. Abdominal aorta. 5. Left common iliac. 6. Femoral artery. 7. Popliteal artery. 8. Posterior tibial artery. 9. Anterior tibial artery. 12. Right innominate artery. 13. Right subclavian artery. 14. Brachial artery. 15. Ulnar artery. 16. Radial artery. 18. Common carotid artery. 19. Temporal artery. 20. Pulmonary artery. 21. Left branch of pulmonary artery.

VEINS.

30. Descending vena cava. 31. Left innominate vein. 32. Right innominate vein. 33 Left subclavian. 34. Axillary vein. x. Cephalic vein. 35. Radial vein. 36. Ulnar vein. 48. Thoracic duct. 49. Jugular vein. 50. Pulmonary vein. 37. Ascending vena cava. 38. Hepatic vein. 39. Portal vein. 40. Renal vein. 42. Gastric vein. 43 Mesenteric vein. 44. Right common iliac vein. 45. Femoral vein. 46. Anterior tibial vein. 47. Posterior tibial vein.

plexus about the abdominal aorta, and quite often on the nerves of the mesenteries. In the mesentery of the cat they may be seen by the naked eye; they have also been found in the pancreas, lymphatic glands, and thyroid glands.

Each corpuscle is somewhat oval in shape, large and more complex than the touch corpuscles or end bulbs. They are one tenth to one fifteenth of an inch long and one twentieth to one thirtieth of an inch broad. Each corpuscle is attached by a narrow pedicel to the nerve on which it is situated. It is composed of several concentric layers of fine membrane made up of a hyaline ground membrane with connective tissue fibers, each layer being lined with endothelium; passing through each pedicel is a single nerve fiber which, after traversing the several concentric layers and their immediate spaces, enters a central cavity, and gradually losing its dark border becomes smaller and terminates at or near the distal end of the cavity, in a knob-like enlargement, or in a bifurcation. These bodies do not occur in the skin proper, but in the subcutaneous connective tissue of the palm of the hand and the sole of the feet, including the fingers and toes, along the nerves near the joint, etc.; being thus deep seated, there is doubt as to their connection with cutaneous sensation.

Touch Proper. — Of tactile sensation we recognize two varieties: (1) sensation of simple pressure and (2) sensation of locality. The mere contact of a body with the skin gives a slight sensation of touch, the sensation becoming more acute up to certain limits as the pressure increases. The sensitiveness to pressure varies in different parts of the skin. This is determined by allowing small weights to press on the skin of various parts, different weights being used, one after the other, and the sensation noticed. By this means it has been determined that the parts most sensitive to the pressure sense are on the forehead, temples, and on the back of the hand, which will detect a pressure of .002 of a gram. The skin of the finger detects a pressure of .005 to .015 of a gram.

In feeling the pulse, where we wish to distinguish small

intermediate variations of pressure, it is better noted with the tips of the fingers than with the skin of the forehead.

When the skin is touched by an object, we not only experience a sensation of greater or less intensity varying with the pressure or the part receiving the pressure, but we are also aware of the part that has been touched. This latter power is called sense of space or locality. In this, as in the pressure sense, not all parts of the body are equally sensitive, nor do they correspond with those most sensitive to pressure. The acuteness of sense of space probably depends on the number of sensory nerves in the part affected; for the fewer the fibers in a given area, the more likely it is that the adjacent points will act on only one and produce but one sensation, and the greater the number of fibers in a given area the more likely it is that the different points will be distinguished and the locality determined. The common mode of determining the sensitiveness of the various parts of the body is by placing the two blunted points of a pair of compasses on a part of the skin, thus determining the smallest distance at which the two points are felt as one impression. From this it is found that the tip of the tongue is most sensitive, and the middle part of the forearm and the middle of the thigh is least sensitive.

From a study of this subject it will be noticed that those parts are most sensitive in such parts of the body as carry out the widest and most rapid movements. The sensitiveness is increased by moistening the skin, but a cold and bloodless condition of the skin blunts the sensibility. The sensitiveness is improved somewhat by exercise. But Mr. F. Galton says that the alleged superiority of blind persons in sensitiveness of touch is not great, as the guidance of the blind depends mainly on the multitude of collateral indications to which they give heed, and not in their superiority in any one of them.

Sensation of Temperature.— The skin, and certain parts of the mucous membrane are capable of temperature sensation. These sensations are of two kinds: sensation of heat, and sensation of cold. They differ from each other, as well

as from the sensation of pressure. When we examine the skin, we find areas which are especially sensitive to heat, called hot spots; there are also areas which are sensitive to cold, which are called cold spots. These areas do not always coincide, nor do they correspond with the points sensitive to pressure. The cold spots are more numerous than the hot spots. These spots are often arranged in lines somewhat curved. The areas are determined by a pointed pencil of copper, by dipping it into hot water and touching parts of the skin; some parts will be found very sensitive to heat while others do not have this sensation. For determining the cold spots a pencil of ice is taken, by which it is found there are spots sensitive to cold, but not to heat. From this difference in sensation it would seem that these different spots have specifically different nerve fibers.

The sensation of heat and cold can only be felt through the nerve endings of the skin. The direct stimulation of the nerve produces only a sensation of pain.

It has been found that —

1. Bodies of the same temperature, as the part of the skin to which they are applied, give rise to no thermal sensation.

2. The parts of the body having the sense of temperature most acute are, in order, the tip of the tongue, the eyelids, the cheeks, the lips, and the hands.

3. Small differences of temperature about two-thirds C. are readily appreciated by the sensitive parts when the temperature lies near that of the body.

4. The power of the skin to recognize changes of temperature is very great, yet our power of estimating absolute temperature by skin sensations is small. Our own feeling of warmth depends on the state of the cutaneous blood vessels, full blood vessels causing us to feel hot, and empty vessels to feel cold. Hence an object at the same temperature will produce upon us different sensations of temperature, accordingly as the skin is full or empty of warm blood.

5. Illusions in this sense are common: a cold weight is heavier than a warm one; a good conductor, like metal, feeling colder than a piece of wood of the same temperature.

THE SENSE OF TASTE.

Organs of Taste. — The principal seat of the sense of taste is the tongue (Fig. 151). We know from common experience and from experiments that this sense also resides

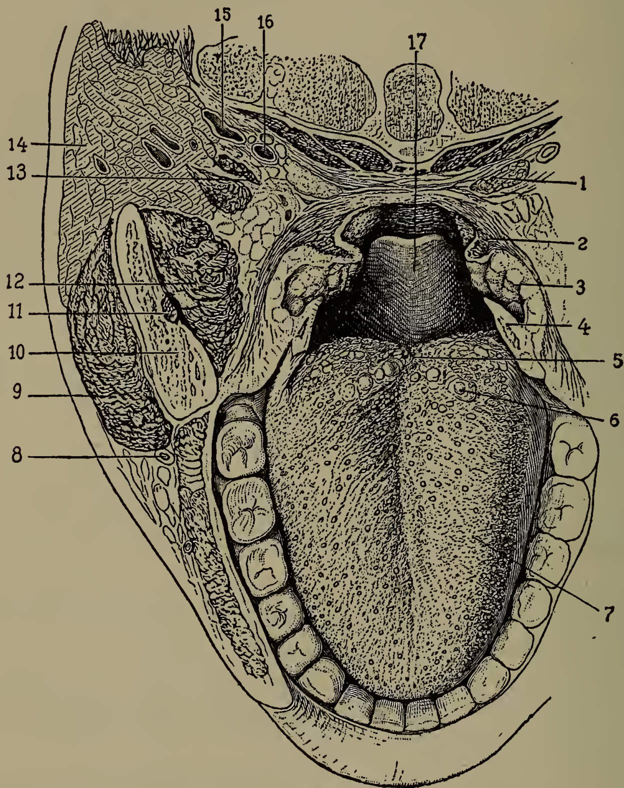


Fig. 151. — The Tongue.

1. Lymphatic gland. 2. Arch of pharyngopalatal muscle. 3. Tonsils. 4. Glossopalatal muscle. 5. Cœcal foramen. 6. Circumvallate papilla. 7. Tongue. 8. Exterior maxillary artery. 9. Masseter muscle. 10. Cut end of maxillary bone. 11. Maxillary foramen. 12. Internal pterygoid muscle. 13. Digastric and stylopharyngeal muscle. 14. Parotid gland. 14. Internal jugular vein. 16. Internal carotid artery. 17. Epiglottis.

in the soft palate and in its arches, in the uvula, tonsils, and probably the upper part of the pharynx.

These parts, together with the base and posterior part of the tongue, are supplied with branches of the glossopharyngeal nerve. In most persons the anterior parts of the tongue, especially the edges and tip, possess the sense of taste. There

are persons who do not seem to be able to taste with these parts.

The middle of the dorsum of the tongue has only feebly the power of taste, due probably to the density and thickness of the epithelia which prevent the sapid substance from penetrating to their sensitive parts.

The Tongue. — The tongue is a muscular organ covered with mucous membrane. By its base, or root, it is attached behind with the hyoid bone, with the epiglottis, and with the fauces. Its under surface is connected below with muscles which form the floor of the mouth. Under the tongue, the doubling of the mucous membrane forms the *frœnum.* A frænum is also found within each lip, at its middle, and one in front of the epiglottis.

The tip and dorsum of the tongue are free. The muscles which form the greater part of the substance of the tongue are called the *intrinsic muscles;* these are attached to the base of the mucous membrane, chiefly, and it is by them that the smaller or more delicate movements are chiefly performed. The muscles by which the tongue is fixed to the surrounding parts, and by which its greater movements are performed, form what are called the *extrinsic muscles.* The mucous membrane of the tongue, for the greater part, is similar in structure to the membrane as found in other parts of the body, except on the dorsum of the tongue, where its structure is similar to that of the skin, consisting of a corium having papillary and superficial epithelial layers. In structure the corium is very much like that of the skin, but is thinner and less compact. It serves as a place of insertion of the muscle fibers of the tongue. On the under surface of the tongue the mucous membrane is thin and smooth. The convex dorsum of the tongue is marked by a slight furrow, or raphe, along the middle line, that ends in a depression called the *cœcal foramen* (Fig. 151).

Papillæ of the Tongue. — The mucous membrane of the upper surface is covered by large papillæ, which give to it a rough appearance. These consist of two kinds, the simple and the compound. The simple papillæ are like those

found in the skin, and are distributed over the whole surface of the dorsum of the tongue between the compound papillæ. They are most numerous in its posterior portion.

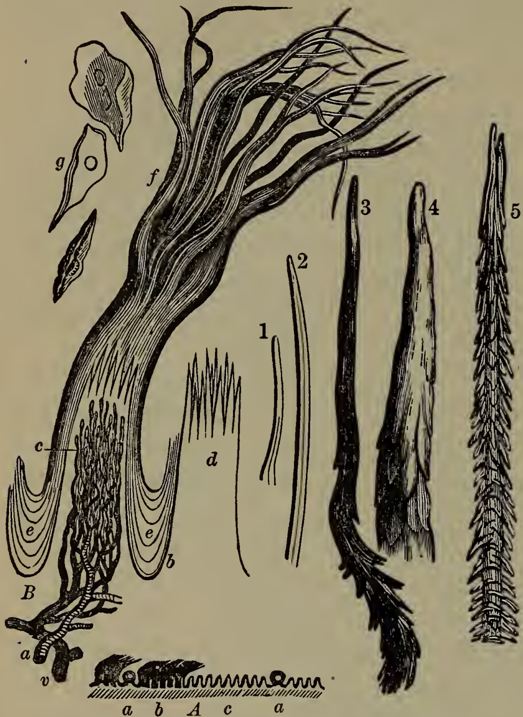


FIG. 152 A.—PAPILLÆ OF THE TONGUE.

A. Vertical section near the middle of the upper surface dorsal) of the tongue. *a.* Fungiform papilla. *b.* Filiform papillæ. Note the hair-like processes. *c.* Filiform papillæ with epithelium removed and magnified two diameters. *B.* Filiform compound papillæ. *a.* Artery. *v.* Vein. *c.* Capillary loop of the secondary papillæ. *b.* Basement membrane. *d.* Secondary papillæ deprived of *e, e,* the epithelium. *f.* Hair-like process of epithelium capping the simple papillæ, magnified twenty-five diameters. *g.* Separated epithelial cells, magnified 300 diameters. 1, 2. Hairs found on the surface of the tongue. 3, 4, 5. Ends of hair-like epithelial processes, showing modes of imbrication of particles, but in all a coalescence of the particles toward the point. 5. Incloses a soft hair, magnified 160 diameters. (After Todd and Boman.)

Of the compound papillæ there are three varieties: the papillæ maximæ, or *circumvallate;* the papillæ mediæ, or *fungiform;* and the papillæ minimæ, or *filiform.*

The circumvallate (Fig. 151) are arranged in two rows, diverging forward from the middle of the back of the tongue in the form of a V. They are ten or twelve in number, and are one twentieth to one twelfth of an inch wide. Each papilla consists of a circular projection having a broad, free surface smaller at the base, and surrounded by a narrow trench, or fossa, on the outside of which the mucous membrane is raised to form a wall or velum. The substance of the papilla is made up of corium, or dermis, formed of dense connective tissue containing blood

vessels and nerves and covered by stratified epithelium. On the papilla are found smaller or secondary papillæ. In the epithelium of the sides of the papillæ are found small oval or flask-shaped bodies called taste buds, or taste bulbs (Fig. 152).

The fungiform papillae are scattered over the surface of the tongue, but are most numerous at the sides and front. They are club-shaped, have a narrow base, and are of a bright red color, due to their rich supply of blood.

The conical, or filiform, the most numerous of the papillæ, are scattered over the whole surface of the tongue, especially over the middle of the dorsum. They vary in shape, but, for the most part, are conical, or filiform. They are covered by a thick layer of epidermis, which is arranged over them, either in an imbricated manner or prolonged from their surface in the form of fine, stiff projections, hairlike in appearance, and in some cases in structure also. It would seem from their peculiar structure that they probably have a mechanical function, or one allied to that of touch rather than that of taste. This latter function is probably seated in the circumvallate and the fungiform papillæ, especially.

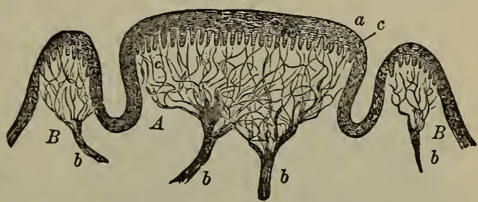


FIG. 152 B. — VERTICAL SECTION OF THE CIRCUMVALLATE PAPILLÆ. (From Kölliker.)
A. The papillæ. *B*. The surrounding wall. *a*. The epithelial covering. *b*. The nerves of the papilla and wall spreading toward the surface. *c*. Secondary papillæ.

Taste Buds. — These (Fig. 153) are found in the epithelium, on the lateral surfaces of all the circumvallate papillæ, in the epithelium of the surrounding velum, in many fungiform papillæ, and in different parts of the general mucous membrane of the tongue, on the under surface of the soft palate and epiglottis. They are oval clusters of epithelial cells, lying in the epithelium and set vertically to the surface, having their broad base resting on the dermis portion of the mucous membrane and their neck opening at a pore on the surface. In each bulb, or bud, is found two kinds of cells: gustatory cells and supporting (*sustentacular*) cells. The former

are small spindle-shaped cells having a central nucleus with an outer process passing from one end to terminate as a fine hair that projects through the gustatory pore, and an inner process which is thought to be continuous with a nerve fibril. The fibril, in fact, may be considered as having its origin in the gustatory cell like a similar arrangement found in the organ of smell. The supporting cells are long and flattened with tapering ends. They are situated between the gustatory cells, and also form a kind of covering for the taste buds. These end buds, by means of the gustatory cells, form the end organs of taste. We are led to believe this from their connection with the fibers of the glosso-pharyngeal nerve, and from the fact that the sense of taste is chiefly found where they are most abundant, and that their cells resemble those of sensory epithelium. There are, however, portions of the tongue which have the power of taste, in which there are no fibers of the glosso-pharyngeal, but which are supplied by fibers from the fifth cranial nerve. The lingual branch of the fifth nerve is therefore considered as gustatory in its functions. There are filaments from the chorda tympani nerve which seem to have close connection with the sense of taste, as is shown from its destruction, producing loss of taste on the same side of the tongue; but its exact connection is but imperfectly understood.

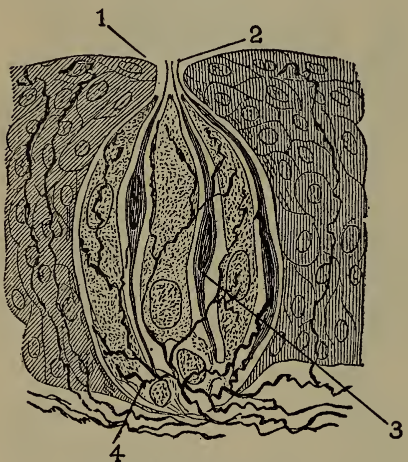


FIG. 153.—TASTE BULB.
1. Depression over goblet. 2. Hair process of taste cells. 3. Nucleus of taste cell (gustatory). 4. Incasing cells.

The various tastes seem to have specific nerves for different parts of the tongue, and each is more sensitive to a

certain taste tnan are the others. The back of the tongue is especially sensitive to bitter; the tip, to sweet and salt; the sides, to acids; and the middle is almost devoid of taste sensation. Weak electric currents applied to the tongue give rise to different kinds of sensations in different parts of the tongue. Cocaine applied to the tongue in increasing doses destroys sensitiveness of all kinds in the following order: general sensation and pain, bitter taste, sweet taste, salt taste, acid taste, and sense of touch.

Among the most clearly defined tastes are those of sweet and bitter, the acid and alkaline, salt and metallic tastes. Acid and alkaline tastes may be excited by electricity.

The delicacy of the sense of taste is sufficient to discern one part of sulphuric acid in 1,000 of water, but in its acuteness it cannot compare with the sense of smell. While the taste apparatus is bilateral, the sensation or perception is single. In this respect taste resembles vision. Much of the perfection of the sense of taste is often due to sapid substances being odorous, and thus exciting simultaneous action of the senses of smell and taste. This is shown by the imperfection of the taste of such substances when action of the olfactories is prevented by a cold or by closing the nostrils.

After Taste.—Very distinct sensations of taste are frequently left after the substances which excited them have ceased to act on the nerve; and such sensation often lasts for a long time and modifies the taste of sweet substances tasted afterward. For example, the taste of sweet substances impairs the flavor of wine; the taste of cheese improves it. There appears to exist a similar harmony between taste as is found between colors; those that are opposed or complementary render each other more vivid, although we have not been able to formulate any general principle governing this relation. In the art of cooking, however, attention is given to this consonance of flavors.

Conditions Necessary.— Substances to be tasted must be (1) either in solution or be soluble in the moisture covering the tongue; for this reason insoluble substances are generally

tasteless; (2) at a temperature of 37° to 40° C. (98° to 100° F.); (3) sentient surfaces. When the tongue and fauces are dry, a sapid substance, even in solution, is tasted with difficulty.

Subjective Sensation of Taste. — The sense of taste may be excited by external cause, as changes in the conditions of the nerve centers, produced by congestion, or other causes which excite subjective sensations in the other organs of sense. We know but little on this subject, as it is difficult to distinguish the phenomena from the effects of external causes, such as changes in the nature of the secretions of the mouth.

Other Functions. — Besides the sense of taste, the tongue, by means of its papillæ, has, especially at its sides and tip, a very delicate and accurate sense of touch, which renders it sensible to impressions of heat and cold, of pain, to mechanical pressure, and to form of surface. It may lose its common sensibility, and still retain the sense of taste, and vice versa. While common sensation and taste may reside in the same papillæ, the separate sensation may be received by different nerve fibers.

Fatigue of Taste.— Like the other special senses, taste may become fatigued. The repeated tasting of one substance rapidly deadens the sensibility, due probably to overstimulation.

Modification of Sense of Taste.— Taste to a great extent is modified by habit, education, and other circumstances. Many articles we have to learn to like; as, tomatoes, olives, and, especially, tobacco. Articles of which we were very fond when young become unpalatable to us when older, and many things which we did not like when children we relish in older age. Certain conditions of the system produce craving for particular articles of diet.

CHAPTER XVII.

THE SENSE OF SMELL.

The Organ of Smell.—The organ of smell is located in a portion of the mucous membrane lining the cavities that are situated between the base of the cranium and the roof of the mouth.

The internal part is formed chiefly of two cavities called the nasal fossæ, opening in front into the air, by the nostrils or anterior nares, and behind into the pharynx by the two posterior nares. The middle wall of each fossa is formed by a vertical partition with a smooth surface. The outer wall on each side is much convoluted. The upper portion, or roof, is formed by the cribriform plate of the ethmoid bone, from which a central vertical plate passes, and is continued downward by the vomer and by cartilage to form the partition between the nostrils, or anterior fossæ. The outer, or side, wall is formed, in part, by two scroll-like bones from the ethmoid, and, in part, by a third similar

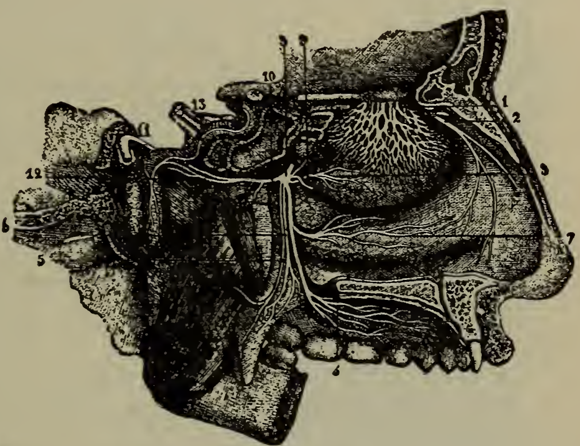


FIG. 154.—NASAL FOSSA AND DISTRIBUTION OF OLFACTORY NERVE.

1. Olfactory nerve. 2. External twig of ethmoidal branch of nasal nerve. 3. Spheno-palatine ganglion. 4. Anterior palatine nerve. 5. Posterior, and 6, Middle, divisions of palatine nerves. 7. Region of inferior turbinated bones. 8. Branch to region of superior and middle turbinated bones. 9. Naso-palatine branch to the septum. (As shown, the branch is cut short.)

bone attached to the superior maxillary. By these three bones (turbinated bones) are formed the three passages called the superior, middle, and inferior meatus, and as we have learned in our study of the cranium, the passages have communication with small cavities, or sinuses, in the surrounding bones.

Mucous Membrane. — All of these cavities are lined with mucous membrane, which is continuous with that lining the pharynx, the Eustachian tubes, and the lachrymal canal to the eye.

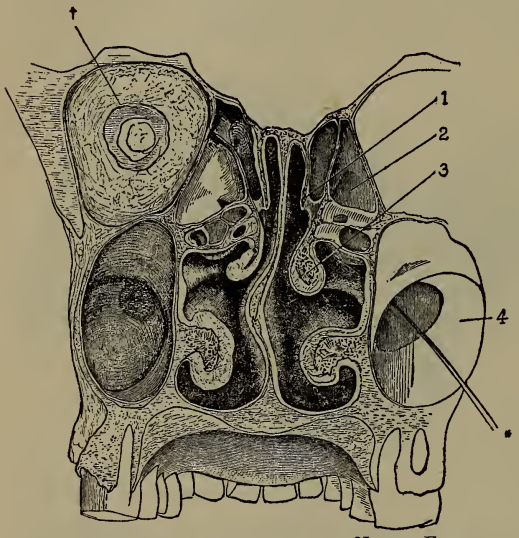


Fig. 155. — Section through Nasal Fossa.
1. Superior meatus. 2. Ethmoid cells. 3. Middle meatus. 4. Maxillary sinus. 5. Inferior meatus.

The nasal mucous, known as Schneiderian membrane, differs in its structure in various parts. It may be divided into three regions: (1) the vestibular region, (2) the respiratory region, and (3) the olfactory region.

The vestibular region is at the entrance of the air passages, whose mucous membrane contains numerous sebaceous glands and hair follicles from which stiff hairs, *vibrissæ,* spring.

In the respiratory region is included the lower meatus, which is lined by thick mucous membrane with numerous mucous glands, and stratified ciliated epithelium.

The olfactory region is the upper, and is the one especially

connected with the sense of smell. It is formed of the anterior two thirds of the superior meatus, the middle meatus, and the upper third of the septum (Fig. 154). In the dermis portion of this region there are numerous blood vessels and nerve fibers, also a large number of peculiar tubular glands having openings between the epithelial cells. The mucous membrane of the olfactory region is soft and of a yellowish tint. The cells are of two kinds: those which are long and cylindrical, having a broad nucleated portion coming to the surface, and forked processes stretching to the corium, or dermis. These are called supporting, or sustentacular cells; those which are long and spindle shaped having a nucleated central part, from which there passes to the surface a slender filament, bearing a free cilium, while another filament passes down to the corium, where it is lost among the nerve fibers, with one of which it becomes connected.

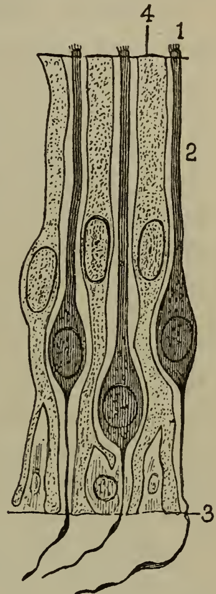


FIG. 156.—OLFACTORY CELLS.

1. Hair-like process of olfactory cell. 2. Their peripheral rods. 3. Their central filaments. 4. Epithelial cells with deep branching processes.

The second variety of cells is called the olfactory, or rod, cells. Among the lower part of the other cells are found rounded cells, called basal cells (Fig. 155). The nerve fibrils which are non-medullated at the base of the epithelium are distributed to the upper third, or olfactory region of the nose, and they have their origin in the olfactory bulb, passing through the cribriform plate of the ethmoid bone, upon which rests the olfactory bulb. These form the nerve of smell, and may be seen forming a brush-like expansion on the upper and middle turbinated bone, as well as on the septum, before they enter the mucous membrane to become connected with the olfactory cells, which are the real end organs of smell. The nose also receives nerve fibers from

the fifth cranial nerve, which are distributed to all parts of the mucous membrane. It has only the power of general sensibility, as is shown by only those parts being sensitive to odors which receive filaments to form the olfactory nerve; and, further, the sense of smell may be lost while the sense of common sensation and pain remains.

Conditions Necessary.— (1) The first condition is the presence of nerve and nerve-end organs, the changes in whose condition stimulate a special nerve center. A substance which excites the sensation of smell in the olfactory center may cause a peculiar sensation through the nerves of taste, and may produce an irritation and burning sensation on the nerves of touch; but the sensation of odor is yet separate and distinct from these, though it may be perceived at the same time. (2) A substance to be perceived by smell must, in case of air-breathing animals, either be solid in a state of extreme division in the air, or in a gaseous condition, and must be soluble in the mucus of the mucous membrane; consequently the mucous membrane must be moist in order to exert this kind of sensibility, as is shown by the impairing or loss of smell when the Schneiderian membrane is dry. (3) In air-breathing animals it is necessary that odors be transmitted in a current through the nostrils. The purpose of sniffing is to render the current stronger and the impression thereby more intense.

The delicacy of the sense of smell is remarkable, it being possible to discern the presence of an odorous substance in quantities so minute as to be undiscovered by spectrum analysis, $\frac{3}{100000000}$ of a grain of musk being distinctly smelled.

The delicacy of the sense of smell varies greatly in different individuals and different animals. As a rule, savage races possess this power to a higher degree than do the civilized. It is highly developed in both carnivora and herbivora. In the acuteness of this sense many animals surpass man, as is seen in the dog which is able to track the animal in the chase by scent, as well as to tell the track of his master.

Subjective Sensation.—The friction of the electric machine produces an odor like that of phosphorus. By Ritter it was observed that when a galvanic current was applied to the organ of smell, besides the impulse to sneeze and the tickling sensation excited by it in the filaments of the fifth nerve, a smell like that of ammonia was excited by the negative pole and an acid odor by the positive.

Frequently a person seems to smell something which is not present; this is especially true of nervous people, but it may happen to every one.

Aside from being a source of pleasure, the sense of smell is protective. While the mouth sense of taste guards the gateway to the alimentary tract from unpleasant and injurious substances, so the sense of smell guards the air passages from injurious gaseous substances.

CHAPTER XVIII.

VISION.

EXPERIMENTS AND DEMONSTRATIONS.

Dissection of the Eye.— Notice the position and relation of the eye in the subject (cat or rabbit) used. Examine the coverings of the eyes (*eyelids*). Notice the number and arrangement of the marginal hairs (*eyelashes*). Do they seem to have any definite arrangement? Compare the outer appearance of the eye you are dissecting with that of the human eye. What difference do you note? How do you account for the difference? Lift the eyelid, and examine margin and under surface with a low power lens. Notice number of the openings near the margin of the lids and the parallel row of bead-like glands (*Meibomian glands*) (Fig. 156). Determine if you can the nature of their secretion. If it is oily, can you think of its use? Examine the lining of the eyelid; trace it over the ball of the eye. This is a mucous membrane, and is called the *conjunctiva.* Lift the lids, and examine the inner angle (*inner canthus*) for two minute openings (*puncta lachrymalia*), one above and one below, and which open into separate canals, which join to form the lachrymal sac, which in turn opens below into the *nasal duct.* Examine the outer angle (*outer canthus*) near its upper border, for a gland (*lachrymal gland*). Determine if you can its opening ducts. This is the gland that secretes the chief fluid for the moistening of the conjunctiva.

With the bone forceps or cartilage knife cut away part of the outer and upper part of the bone of the orbit. With scissors cut away the membrane that covers the front of the eyeball. Notice how it is reflected over the under surface of the eyelids. Do you see any difference in the part that

covers the eyeball from that which lines the lids? This will expose the surface of the eyeball. Look for seven muscles joined to the eyeball.

Notice: (1) the one which follows the roof of the orbit and is attached to the upper eyelid (*levator palpebræ superioris*), and which has its origin near the entrance of the optic nerve into the orbit; (2) the one which has its origin near the same place as the levator, takes an outward and oblique direction to the inner and upper part of the orbit, passes through a pulley, and then back to join to the eyeball at its nasal side (*superior oblique muscle*) (Fig. 157); what movement would its contraction give to the eyeball? (3) the muscle just below the one which moves forward and is joined to the upper part of the eyeball (*superior rectus*); (4) the muscle below the superior rectus, originating by two tendons passing forward and attached to the temporal side of the eyeball (*external rectus*); (5) the muscle having a similar origin, but on the opposite side of the optic nerve, passing forward and inward to join the nasal side of the eyeball (*internal rectus*); (6) the muscle passing downward and forward and inserted to the lower forepart of the eyeball (*inferior rectus*); (7) the muscle originating from the inner angle of the orbit passing forward and inserted to the nasal side of the eyeball inward and below the external rectus.

Notice the entrance of the optic nerve. With the bone forceps cut away the bone, and trace the optic nerve as far as you can. Notice the crossing (*the chiasma*).

For the dissection of the eyeball it is best to use the eye of the ox or sheep, which may be obtained of the butcher.

Hold the eyeball on the dissecting board with one hand, and with a pair of sharp scissors carefully make an incision through the cornea near the margin. With a pair of forceps gently raise the cut edge of the cornea so that the scissors may be inserted, and it may be cut around and removed without injuring the iris. Notice the dark membrane (*iris*) which is thus exposed. Notice the shape and size of the opening (*pupil*) in its center. With the forceps lift up the margin, and determine whether it is attached to the bodies beneath. Notice the coloring and markings of the iris.

Cut around the margin of the iris. Notice the form and nature of the body (*crystalline lens*) now exposed. Make

a light gash across the surface of the lens; cut through the outer coat (*the capsule of the lens*), which envelopes the lens. Gentle pressure with the thumb and finger on the side of the eye will cause the lens to be forced out. Place it on a clean piece of writing paper. Put it on a piece of newspaper, and examine the printing with it. Is there anything in its appearance to suggest its name?

Make a drawing of the lens as it lies flatwise, and when lying edgewise. Compare the curve of the anterior and posterior surfaces. Enlarge the opening that has been made by cutting away the structure which covered the lens. On the inside of the strips thus removed there may be found radiating black ridges (*the ciliary processes*). Remove everything from the clear mass beneath (*the vitreous humor*). Notice its consistency. Notice the entrance of the optic nerve and the blood vessels, which may easily be seen through the transparent vitreous humor.

If the light is not sufficient, view the specimen in stronger light. Now examine the tough outer coat (*the sclerotic coat*). Beneath this tough coat examine the dark coat (*choroid coat*). How does it compare in its supply of blood vessels with the other coats?

Examine the inner, nearly transparent, coat (*retina*). How do you account for its pinkish tint? The color of the retina may be better seen by removing the vitreous humor. Determine if you can the relation of the retina to the nerve which enters the back of the eyeball (the *optic nerve*).

Carefully remove the retina, making note of the layer and its consistency. The dark coat left on the layer beneath (the *choroid*) is the pigment layer of the retina which adheres to the choroid.

Turn the eye inside out, and carefully tear away the choroid coat, and notice how the blood vessels pass from one coat to the other.

Experiments. — 1. Place two pins at each end of a shingle or thin board eight or ten inches long. Hold the board so that it will be about the distance used in reading, and so that the pins will be in line with the eye. Look closely at

the first pin, and notice that the second is not clearly seen. Now look closely at the second, and notice that the first is not clearly seen.

2. Hold the point of a pencil so that it will be in line with some object on the wall, as a picture. Look closely at the tip of the pencil, notice the picture becomes dim; now look closely at the picture which now becomes clear and the pencil dim. How shall we account for the changes noticed in the last two experiments?

3. Examine some object, as a lamp or vase, by means of a double convex lens (a reading glass), moving the lens forward or backward until you see the object inverted. With the lens unchanged in position, move the object forward. What effect has it upon the clearness of the image? Now move the object until the image is clear again. How does your distance from the object compare with the first distance? Take the first position from which you viewed the object, and view the object at its farthest distance by means of a double convex lens of greater curvature than the first. What is the effect? Now view the object with a lens of smaller curvature than the one first used. Which gives you the clearer image?

Since it is not convenient for us to go to the objects in order to see them clearly, how could the parts of the eye be arranged so as to enable us to see distant objects without the trouble of going nearer to them?

What would be the effect if the crystalline lens had the power of changing its curve? To determine this, darken the room, and admit beams of light through two small holes about an inch in diameter. Put in their path lenses of different degree of curvature. Notice the effect. Which bends the rays most? To focus distant objects, which must the crystalline lens be, of smaller or greater curvature than for near objects?

4. Place two small, black objects about two feet apart on a table covered with white paper. Close the left eye, and fix the right steadily on the left object, varying the distance from the object. At a certain distance the right object will disappear. If the object be brought nearer or farther, then it will be plainly seen. This shows us that all parts of the retina are not equally sensitive to light. When the object disappears, the image falls on the part at

which the optic nerve enters the eyeball. As this part is not sensitive to light, it is called the blind spot.

5. Determine at what distance you can see the letters in Fig. 161. By normal eye these should be seen at twenty feet. Do you have to take them farther away or bring them nearer to see them?

6. Remove from the posterior part of an eyeball the sclerotic coat. Direct it upon some well-lighted object, and an inverted image will be seen on the retina through the thin choroid. Remove the lens; note the effect. Why is the image blurred or not apparent?

7. With a hand mirror reflect the sunlight on a white wall. Look at the spot for a minute or more, and then suddenly remove the mirror. Notice a dark spot appears, the complementary color of white.

8. Look steadily at a bright light. Turn away suddenly, or shut the eyes. Do you still see the light? Look steadily for a few seconds at a well-lighted window. Turn the eyes suddenly to a dark wall. Do you still see the window frames? Notice the image on the wall is a negative one, the light parts being dark and the dark parts of the object light in the image.

9. Rotate a stick slowly, and then increase the speed. Does the stick appear to make a continuous circle? How do you account for what you see? What properties of the retina do the three last experiments show?

How are what they call moving pictures made? Upon what principle do we see continuous pictures?

10. Take a circular piece of cardboard, five or six inches in diameter. Paint on it alternate rings of different colors; support by means of a pin so that the cardboard can be rotated. What kind of colors are the red and yellow? What is the color you get by rapid rotation?

11. Draw lines as represented in Fig. 162. Can you see all the lines with the same clearness?

VISION. — TEXT.

Appendages of the Eyes.—These are structures connected with the eye for its protection. The chief of these are the eyelids and the lachrymal apparatus. The eyelids are composed of a dense fibrous tissue (*tarsal cartilage*) covered ex-

ternally by the skin and internally by a mucous membrane called the *conjunctiva.* Beneath the skin are the fibers of the orbicularis for closing the eyelids, and in the eyelid there is, in addition, the levator palpebræ for elevating the lid, and in the lower lid the depressor palpebræ to draw down the lower lids.

On the inner margin of the eyelid may be seen the minute openings of a variety of sebaceous glands called the

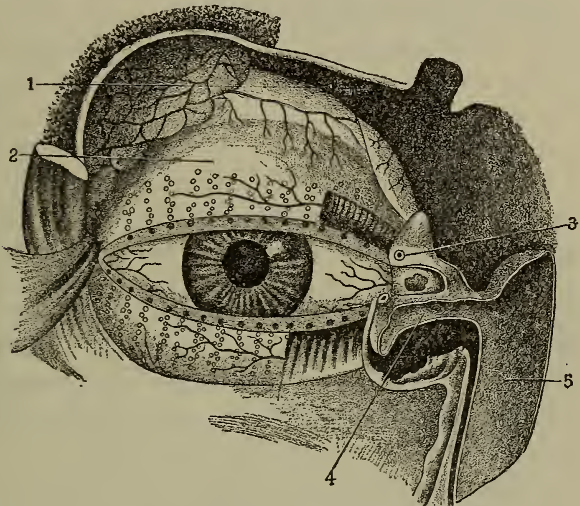


FIG. 157.—LACHRYMAL APPARATUS.

1. Lachrymal gland. 2. Meibomian glands. The dots along edge of eyelid are the openings of the Meibomian glands. 3. Tear pore (puncta lachrymalia). 4. Canaliculus. 5. Nasal duct.

Meibomian glands, as seen through the conjunctiva, containing thirty rows on each side. Sometimes one or more of these become inflamed, producing what is called a sty.

Along the free edges of the lids curved hairs, eyelashes, grow from large hair follicles to which sebaceous and modified sweat glands are attached.

After lining the eyelid, the conjunctiva is reflected over the front of the eyeball, becoming adherent to the sclerotic coat, its epithelial portion only passing over the cornea. The conjunctiva of the lids is thicker than the other portions, very vascular and sensitive, being freely supplied with nerve

filaments, and has a number of mucous glands where reflection begins.

While the mucus aids in some degree in keeping the surface of the eye moist, the chief fluid for this purpose is the secretion from the *lachrymal gland.* This gland is situated (Fig. 157) in the upper and outer part of the bony orbit with its under surface resting on the eyeball. It is oval in shape and about the size of an almond. In structure it is a compound (*racemose*) gland consisting of several lobules, the *acini,* which are lined by cylindrical granular epithelium, being similar to that of a serous salivary gland. It opens by several ducts on the inner surface of the upper lid. Its watery secretion spreads over the eyeball, where its overflow is usually prevented by the oily secretion of the Meibomian glands (Fig. 156) on the edge of the lids, and after passing over the surface of the eyeball, it collects in the inner angle (*canthus*) of the eye. Here it passes off by two small openings (*puncta lachrymalia*), one above and one below, into two small canals (*canaliculi*) that unite to form a sac (*lachrymal sac*). This sac opens below into the *nasal duct* (Fig. 157), which runs in a groove of the superior maxillary bone and ends in the lower meatus of the nose.

Like other secretions, it is under the control of a special center of the nervous system. Various sensory impulses, as pungent smells or irritating vapors, may produce reflex stimulation of this center, and lead to such a copious secretion that the liquid overflows as tears. Strong emotions, as great joy, or sorrow, may produce the same effect.

The Eyeball.— The eyeball is nearly spherical in form, and consists of segments of two spheres of different sizes. The front portion, amounting to about one sixth of the eyeball, is a segment of a small sphere; the posterior portion forming the rest of the eyeball is a segment of a larger sphere. It is composed of three layers, which inclose fluids and solid bodies called *humors* (Fig. 158). The investing coats are (1) the outer tunic, consisting of the *sclerotic coat* and *cor-*

nea; (2) the middle tunic, made up of *choroid, iris,* and *ciliary* processes; (3) the inner tunic, *retina,* spread out over the inner and back portion of the choroid. The refracting media or humors are, in order from before backward,—the aqueous humor, the crystalline lens, and the vitreous humor. By the iris and crystalline lens the interior of the eye is divided into two chambers, a small *anterior chamber* which contains the aqueous humor, and a *posterior chamber* containing the vitreous humor.

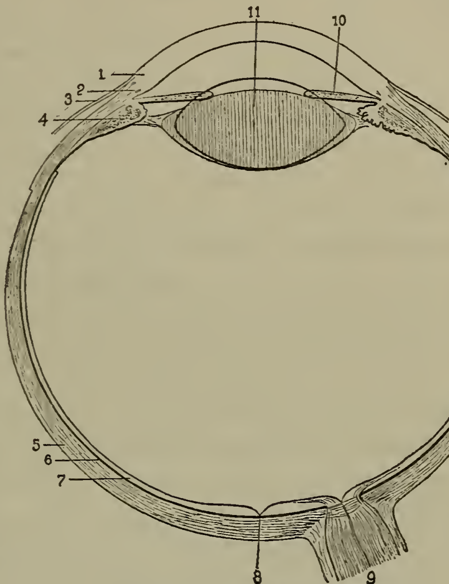


FIG. 158.—COATS OF THE EYEBALL.
1. Cornea. 2. Sinus venosus. 3. Conjunctiva. 4. Ciliary muscles. 5. Sclerotic. 6. Choroid. 7. Retina. 8. Fovea centralis. 9. Optic nerve. 10. Iris. 11. Crystalline lens.

Outer Tunic.—*The sclerotic coat* (Fig. 158).—This is the strong, dense fibrous membrane which forms the posterior five sixths of the outer tunic of the eyeball. Its external surface is white (forming the white of the eye), and receives the insertion of the muscles of the eyeball (the *recti* and *oblique muscles*); its inner surface is brown, and connected by fine cellular tissue to the outer surface of the second coat. It is composed of white fibrous tissue with some fine elastic fibers and numerous connective tissue corpuscles. Behind, a little to the inner or nasal side, it is pierced by the *optic nerve,* the fibrous sheath of the nerve becoming blended with that of the sclerotic. Near the entrance of the optic nerve it is also pierced

by small arteries and nerves, the ciliary arteries and nerves, which are distributed to the sclerotic, choroid, and iris. The artery for the retina passes in through the middle of the optic nerve, its branches being distributed to the inner surface of the retina.

Cornea.— This is the transparent circular membrane (Fig. 17) forming the fore part of the outer tunic, set, as it were, into the sclerotic, with which it is continuous all around. It consists of: A stratified layer of epithelial cells, derived from the conjunctiva and continuous with that layer of eyelids; an anterior elastic lamina beneath it, about one twenty-fifth of an inch thick, is made up of five layers. The cornea is covered by stratified epithelium, consisting of seven or eight layers of cells, the superficial one being flattened and scaly, and the deeper ones more or less columnar. Just below this is the anterior homogeneous lamina of Bowman, which differs from the general structure of the cornea in being more condensed. It is composed of an intercellular ground substance of rather obscurely fibrillated flattened bundles of connective tissue, arranged parallel to the free surface, and forming the boundaries of branched anastomosing spaces in which the corneal corpuscles lie. These corpuscles have been seen to execute amœboid movement. Limiting the posterior surface is the posterior homogeneous lamina (*membrane of Descemet*), which is elastic in its nature. The inner surface of the cornea (Fig. 17) is bounded by a single layer of cubical epithelial.

The cornea is devoid of blood vessels, except a few capillaries at its circumference. Its nutrition is effected by the passage of the lymph through branched spaces in which the corneal corpuscles lie.

The nerves of the cornea are large and numerous, and are derived from the ciliary nerves. They traverse the substance of the cornea in which some of them near the anterior surface break up into axis-cylinders, and their primitive fibrillæ. The latter forms a plexus beneath the epithelium, from which delicate fibrils pass up between the cells, anasto-

mosing with horizontal branches and forming an intra-epithelial plexus. Most of the primitive fibrillæ have a beaded appearance. This is what makes the conjunctiva so sensitive to particles of dust, etc. Running round the margin of the cornea in the sclerotic is a small lymphatic channel called the *canal of Schlemm*.

The Middle Tunic. — This is made up of the choroid, and, like the sclerotic, is found on the posterior five sixths of the eyeball. It is a highly vascular membrane, its blood vessels being derived from ciliary arteries and veins. The vascular network is held together by elastic connective tissue in which lie large stellate corpuscles and dark pigment. This pigment serves to assist in absorbing the light entering the eye and prevents absorption.

Resting upon a fine elastic layer (*membrane of Bruch*) is a denser layer of blood vessels, which serve to nourish the underlying pigment layer of the retina.

The choroid coat ends in front in seventy or eighty meridionally arranged radiating plates (*ciliary processes*), which consist of blood vessels, fibrous connective tissue, and pigment corpuscles. They are lined by a continuation of the membrane of Bruch. The ciliary processes end abruptly at the margin of the crystalline lens.

From the junction of the cornea and sclerotic arises the ciliary muscle. This is a ring of muscle 3 mm. broad and 8 mm. thick, made up of fibers running in three directions: (1) Meridional fibers near the sclerotic; (2) fibers passing to be inserted into the choroid behind the ciliary processes; and (3) more internal circular fibers, forming a sphincter muscle (*muscle of Müller*).

The ciliary muscles thus form a ring around the eye between the sclerotic and ciliary processes, and their contraction draws the choroid forward, and thus relaxes the suspensory ligaments of the crystalline lens, making the lens more convex, and aiding, as we shall see, in the accommodation (Fig. 163) of the eye.

The continuation of the choroid inward beyond the cil-

iary processes forms the iris. It is a fibro-muscular membrane, perforated by a central aperture, the pupil. It is composed chiefly of blood vessels and connective tissue with pigment and unstriated muscle. On its posterior surface is a pigment layer derived from the retina.

The iris proper is made up in front of connective tissue with corpuscles which may or may not contain pigment, and, behind, of a similar tissue, supporting blood vessels inclosed in connective tissue. This part of the pigment cells is usually well developed, as also are many nerve fibers radiating toward the pupil. Surrounding the pupil is a layer of circular unstriped muscle, the *sphincter pupillæ.* In some animals there are also muscle fibers which radiate from the sphincter into the substance of the iris, forming the dilator pupillæ. Anteriorly the iris is covered by a layer of epithelium continued upon it from the posterior surface of the cornea.

Retina.— The retina (Fig. 159) is a delicate semitransparent membrane forming the inner, or third, tunic of the eyeball. It conforms in its curvature to the inner surface of the eye, being directed forward and apparently ending in front near the outer part of the ciliary processes in a finely notched edge (*ora serrata*), but really present to the very edge of the pupil. When fresh, it is semitransparent, slightly pinkish in tint, due to its blood vessels, but it becomes clouded and opaque on standing. It is from the expansion of the optic nerve, of whose fibers, with nerve cells, it is essentially composed. In the exact center of the retina is to be seen a round yellowish spot (*macula lutea or yellow spot of Sömmerring*), about one twenty-fourth of an inch in diameter, and having in its center a small depression (*fovea centralis*). The optic nerve enters about one tenth of an inch in the inner part of the yellow spot.

As the optic nerve passes forward from the ventral surface of the cerebrum to the orbit, it is invested by prolongations of the dura mater, arachnoid, and pia mater. At the entrance of the nerve into the eyeball the external sheath becomes

continuous with the sclerotic, which at this part (*lamina cribrosa*) is perforated with holes to allow the passage of the optic nerve fibers and the pia mater with the choroid. At this point the pia mater becomes incomplete, and the subarachnoid and the superarachnoid spaces become continuous. From the pia mater is given off processes to sup-

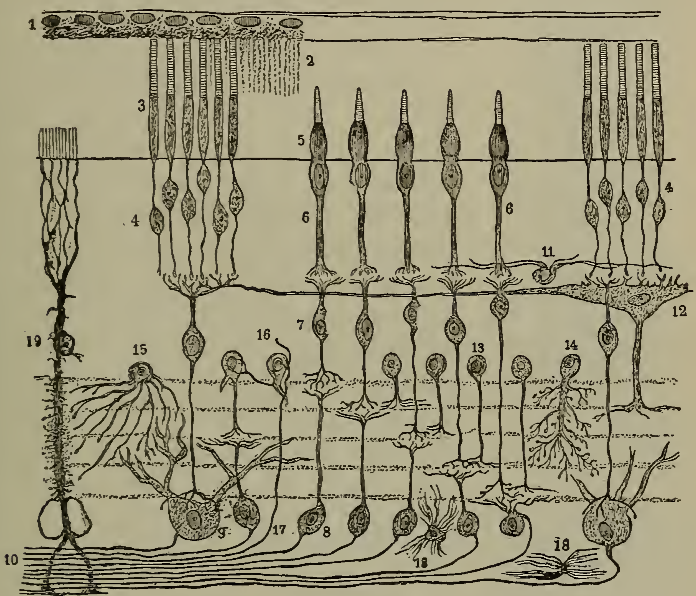


FIG. 159 A.—DIAGRAM OF THE ELEMENTARY STRUCTURE OF THE RETINA.

1. Pigment cells. 2. Filaments of pigment cells. 3. Rod. 4. Body of rod cells. 5. Cone cells. 6. Filament of cone cell. 7. Bipolar cell. 8. Ganglionic cells ramifying in the various strata of the internal molecular layer. 9. Large ganglionic cells joining with the inferior arborescence of the bipolar cells. 10. Fibers of optic nerve. 11. Horizontal cells. 13, 14, 15, 16. Many-formed cells of the inner reticular or molecular layer. 17. Centrifugal nerve fiber. 18. Neuroglia cells. 19. Epithelial cell (Müller cell).

port the nerve fibers. The nerve fibers are very fine, without their ordinary external nerve sheath, but having a little delicate myelin sheath; but as they pass into the retina, they lose their myelin sheath, and proceed as axis-cylinders. The nerve fibers of the optic nerve trunk are supported by neuroglia. In the center of the optic nerve is a small artery (*arteria centralis retinæ*).

The number of fibers in the optic nerve has been estimated to be over 500,000.

The retina[1] consists of nervous elements arranged in several layers and supported by a delicate connective tissue. These elements may be divided into two kinds: (1) the supporting connective tissue (*sustentacular*) (Fig. 159) and (2) the nervous (Fig. 159).

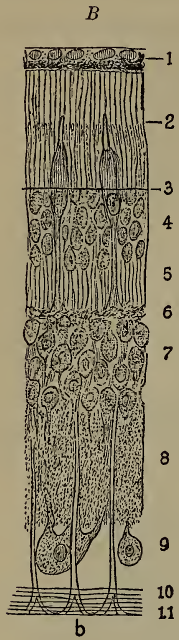


FIG. 159. B.—LAYERS OF THE RETINA.

1. Pigment layer. 2. Layer of rods and cones. 3. External limiting layer. 4. External molecular layer. 5. Spaces for the nervous elements and fibrous layer. 6. External granular layer. 7. External nuclear layer. 8. Internal granular or molecular layer. 10. Fibers of the optic nerve. 11. Internal limiting membrane.

Structure of the Retina in Different Parts. — Toward the yellow spot all the layers of the retina become greatly thinned out, and almost disappear, except the rod and cone layers, which increase in thickness, but at the fovea centralis consist almost entirely of cones and cone fibers. Toward the edge of the yellow spot all the layers are present, but the ganglion layer increases in prominence, being made up of many layers of cells. At the optic pore, where the optic nerve enters the eye, only fibers are present, and as this part is insensitive to light, it is called the *blind spot*.

At the ora serrata of the nerve fibers, ganglion cells and rods have disappeared, and over the ciliary process the retina proper ceases, there being only the layer of cells known as the *pars ciliaris retinæ*.

---

[1] In a vertical section, the following ten layers, naming from within outward, are usually distinguished—

1. *A Delicate Membrane* (*Membrana Limitans Interna*) (*Fig. 159*).—This is in contact with the vitreous humor. This seems to bear the same relation to the retina as the neuroglia does to the nerve tissue, that of a supporting character. This may be seen by a study of Fig. 159.

2. *Optic Nerve Fiber.*—This is a layer varying greatly in thickness in different parts of the retina. It consists of non-medullated fibers which interlace, some of which are continuous with the processes of the nerve cells which make up the

The Chambers of the Eye.— The space behind the cornea and in front of the crystalline lens is called the anterior chamber. It is filled with the aqueous humor. The portion back

---

next layers. The fibers are supported by the connective tissue (*sustentacular fibers*). The nerve fibers become less numerous anteriorly, and end at the ora serrata.

3. *Layer Ganglionic Corpuscles.* — This layer consists of large multipolar nerve cells having prominent nuclei. In the yellow spot this layer is very thick, being made up of several layers. The cells are imbedded in the spaces of the connective tissue network, and so arranged as to have their axis-cylinder processes inward, being continuous with the layer of the optic nerve fibers. Above, the cells become much branched.

4. *Inner Molecular Layer.* — This layer is fine, granular in appearance. It is made up of a *fungiform* connective tissue traversed by numerous, very fine fibrillar processes of the nerve cells and the minute branches of the processes of the nuclear cells of the layer above.

5. *Inner Nuclear Layer.* — This is composed chiefly of small, round cells, which consist of a small amount of protoplasm and a large ovoid nucleus, most bipolar, giving off one process outward and another inward. The cells vary much, resemble the ganglion corpuscles of the cerebellum, and are of three kinds.

6. *Outer Molecular Layer.* — In structure and appearance it closely resembles the inner molecular layer, but it is much thicker. It is made up of finely dotted connective tissue and nerve fibrils of the branchings of the rod and cone fibers above, and of the inner cells below.

7. *External Nuclear Layer.* — This layer is made up of small cells resembling those of the internal granular layer; they have been classed as rod and cone fibers, accordingly as they are connected with the rods and cones respectively. They are lodged in the meshes of the connective tissue framework.

8. *Membrana Limitans Externa.* — This is a delicate, well-defined membrane, which clearly marks the internal limit of the rod and cone layer, being made up by the junction of the bases of the sustentacular fibers, externally. The rods and cones are supported by small hair-like processes which project outward between them.

9. *Layer of Rods and Cones.* — This is probably the most important layer of the retina. It is thought to be directly or indirectly continuous with the nervous layer proper. The bodies of which it is composed are arranged at right angles to the external limitans membrane and are similar in general form but vary in certain details, and are supported by the hair-like processes from the external limitans membrane.

THE RODS. — Each rod is made up of two parts which differ very much in structure, and are known as the outer and inner limbs. The outer limb of the rod is transparent, doubly refractive, about 30μ long 2μ broad. It is said to be made up of fine superimposed disks. It resembles in some ways the myelin sheath of a medullated nerve. It swells on exposure to light, and is part of the layer in which the pigment called visual purple is found. The inner limb is longitudinally striated at its outer part and granular at its inner part; it has about the same length as the outer limb, but is broader. Each rod is connected internally with the rod fiber, the internal end of the rod fiber terminating in minute branches in the internuclear layer.

THE CONES. — Like the rods each cone is made up of two limbs. The outer limb is tapering, about one third the length of the corresponding part of the rod, and similar to it in structure. There is no visual purple found in the cone. The inner limb of the cone is broader in the center. Each cone is connected by its internal end with a cone fiber which has a structure similar to that of the rod fiber, but is much stouter, and with its nucleus nearer the external limitans membrane. The tunic portion of the inner end is like that of the outer. In the retina of man the rods are far more numerous, except in the fovea centralis where only the cones are present, and also in the anterior part of the retina

of the crystalline lens and bounded by the retina is called the posterior chamber. It contains the vitreous humor.

Humors of the Eye.— These are the aqueous humor, the crystalline lens, and the vitreous humor. As has been stated, the aqueous humor is contained in the anterior chamber of the eye. It is essentially a diluted lymph with a small amount of proteid material. It contains salts, the chief of which is sodium chloride, sometimes a substance which reduces copper sulphate; but it is not sugar, and has traces of urea and sarcolactic acid. By some it is thought that the aqueous humor is secreted by glands in the ciliary region, but the cavity itself is without doubt a lymph sac.

The Crystalline Lens.—This is situated behind the iris, being supported in place by the suspensory ligaments fused to the anterior surface of the capsule. The suspensory ligament is derived from the membrane (*hyaloid*) which incloses the vitreous humor. It is biconvex, having its posterior surface of greater curvature than its anterior. It consists of a capsule and lens. The capsule is a transparent, elastic membrane, and strongest in front. The lens consists of a number of concentric laminæ which, after hardening, may be peeled off like coats of an onion, each lamina consisting of ribbon-like fibers with serrated edges. The inner laminæ are closely applied, and form a dense core, or nucleus. The fibers which are developed by the elongation of cells run

---

near the ora serrata. It has been estimated that there are about three million cones in the retina of man. In most birds, cones usually predominate in number, but in nocturnal birds and some nocturnal animals, as the bat, hedgehog, mouse, and mole, only rods are present.

10. *Pigment Cell Layer.*—This layer was formerly considered as a part of the choroid. It consists of cells which cover and entirely surround the outer limbs of the rods and cones. This is a single stratum of hexagonal epithelial cells, containing black pigment. They are present in all parts of the retina except at the entrance of the optic nerve. The outer part of the cell is smooth and flat, but the inner part is prolonged, on exposure to light, into fine processes that extend between the rods. The pigment granules lie in the inner part of the cell, and after exposure to light extend along the prolonged cell processes, where by their agency, the visual purple of the retina becomes developed in the outer part of the rods. There is no pigment in the cones. Visual purple is bleached by exposure to light, and the function of the pigment cells appears to be to restore the purple coloring matter after being bleached by light. Light causes the processes of the pigment cells to extend inward between the rods, while darkness causes the processes to retract.

from front to back, being so arranged that no fibers from one pole of the lens go to the other (Fig. 158). The lens contains no blood vessels, its nutrition being effected by the blood vessels of the choroid.

Vitreous Humor.—The vitreous humor occupies the posterior chamber of the eye. It consists of a semifluid substance contained in the meshes of an indistinct connective tissue. It is inclosed by a distinct membrane (*membrana hyaloidea*) from the anterior surface of which, at the ora serrata, fibers pass off to the back of the lens capsule, forming an incomplete canal (*canal of Petit*). Fibers also pass forward over the ciliary processes to be attached to the capsule of the front surface of the lens to form the suspensory ligament (*zonule of Zinn*). It contains water, with a little over one per cent of proteid matter and salt. The fluid appears to belong to the same system as the aqueous humor, there being a communication through the suspensory ligaments. As it has no blood vessels in the adult, it must derive its nutrition from the surrounding vascular structures. There is a small canal passing from the back forward and terminating at the capsule of the lens. This canal (*canal of Stilling*) takes the place of an artery which exists in the fœtus.

Blood Vessels of the Eye.—The eye is richly supplied with blood vessels. Supplying the eyelids and glands are the palpebral and lachrymal branches, and the conjunctival branches which pass also to the edges of the cornea. The coats, or tunics, of the eyeball are supplied by two distinct sets of vessels: (1) the vessels of the sclerotic, choroid, and iris, and (2) the vessels of the retina. The former are the short and long posterior and anterior ciliary arteries. The short posterior ciliary arteries enter the first part of the sclerotic around the optic nerve (Fig. 160), and are distributed to the choroid and ciliary processes. The long posterior ciliary arteries enter the choroid behind, and passing forward, are distributed to the ciliary muscles and to the iris, and with the anterior ciliary, which enters near the insertion of

the recti muscles, form by their anastomosis the rich choroidal plexus. They also supply the iris and ciliary processes, and form a very highly vascular circle around the outer margin of the iris and adjoining portion of the sclerotic.

The bloodshot eye is due to congestion of the conjunctival vessels, while the pink zone sometimes surrounding the cornea indicates deep-seated ciliary congestion, and the distinctness of the two sets of vessels may be thus indicated. From the capillaries numerous veins arise, which form a vorticose arrangement on the surface of the choroid, and unite for the most part into four large trunks that pass out of the choroid about midway between the cornea and the optic nerve.

The retina is supplied by branches from the arteria centralis retinæ, which enters the eyeball along the center of the optic nerve. It gives off branches which ramify all over the retina, but chiefly in its inner layers. The capillaries unite to form a central canal. Except near the entrance of the optic nerve the two sets of blood vessels of the eyeball are quite distinct.

Nerves of the Eye.— The optic nerves are the special nerves of vision. Passing backward from the retina, the two optic nerves meet, ventral to the floor of the third ventricle, and cross each other, forming the optic chiasma; they then continue under the name of optic tract. In the chiasma the decussation of fibers takes place. In man the fibers which belong to the temporal half of the eye, in which the nerve ends, pass into the optic tract; i. e., of the same side, while the fibers which belong to the nasal half pass into another tract, the optic tract of the opposite side. Thus the fibers of the temporal half of the right eye and the nasal half of the left eye pass into the right optic tract, and the fibers of the temporal half of the left eye and the nasal half of the right eye pass into the left optic tract. It will be noticed from this that the temporal half of one eye corresponds to the nasal half of the opposite eye, and that each optic tract contains fibers from half of each eye. The degree to which

the decussation takes place varies in the different types of animals, the difference having reference to the amount of binocular vision, and this in turn having relation to the position of the eye and the prominence of the facial features; e. g., in fish, with laterally placed eyes, binocular vision is not possible, so that the decussation of the fibers is complete.

The chiasma also contains in its hinder part fibers which have no connection with the optic nerves or the eyes; they are simply commissural tracts passing from one side of the brain, from the median corpus geniculatum along one optic tract through the chiasma to the other optic tract and to the median corpus geniculatum of the other side of the brain.

Each optic tract crosses obliquely, being in crossing firmly attached to the ventral surface of the crus cerebri of the same side, and is soon lost to view, being covered by the temporo-sphenoidal lobe of the cerebrum. By removing this lobe, the optic tract is brought to view, and is seen to sweep dorsally around the crus toward the dorsal side to become connected with the two (lateral and median) corpora geniculata (Fig. 62). The fibers which come from the median corpora probably have no concern with vision, but are, as has been stated, simply commissural. The fibers concerned with vision end in three main ways: (1) those in the lateral corpus geniculatum; (2) a very large number of fibers pass the corpus geniculatum on its ventral and lateral surface spread out into the pulvinar; (3) those which take a more median direction pass to the corpus quadrigeminum. It is probable that all of these centers are concerned with vision. While the areas mentioned are the chief endings of the optic nerves and the three primary visual centers, there are good reasons for believing that some of the fibers of the optic tract pass by the crus cerebri straight to certain parts of the cerebral hemisphere, although their endings have not been made out. The trophic center of the optic nerve is in certain cells of the retina, as is shown by section of the optic nerve on removal of the eye of an adult animal, which leads to degeneration in the optic nerve and optic tract.

In addition to the optic nerve, other nerves enter the eyeball. The ciliary nerves pierce the sclerotic around the optic nerve. These are mainly branches of the first, or ophthalmic, division of the fifth cranial. Accompanying them are branches from the sympathetic system. After passing through the sclerotic the ciliary nerves run forward between it and the choroid, and are distributed to the iris and ciliary muscles. There are twigs from the first branch of the fifth nerve which supply the cornea; fine fibrils passing between the epithelial cells to the conjunctival layer giving to it its acute sensibility to foreign particles. Disease or injury of this branch of the fifth nerve destroys the sensibility of the surface of the eyeball. The vasomotor fibers to the blood vessels are included in the ciliary nerves.

The chief motor nerves of the eye are the third pair of cranial nerves (*motores oculi*). Each motor oculi supplies all the muscles of the eye except the superior oblique and external rectus; it also sends filaments to the elevator of the eyelid and to the iris and ciliary. In addition to controlling the movement of the eyeball, this nerve regulates the amount of light entering the pupil, and brings about accommodation. A bright light acting through the retina and optic nerves stimulates the center of origin of this nerve, exciting reflexly the pupil to contraction.

The fourth pair of cranial nerves (*trochlearis*) supplies the superior oblique muscle of the eye. The sixth pair of cranial nerves (*abducentes*) supplies the external rectus muscle.

Muscles of the Eye.— The upper lid is raised by the *levator palpebræ superioris;* the *orbicularis palpebræ* close the eyelids. There are six muscles (Fig. 161) which are concerned with the movements of the eyeball, four straight muscles (*recti*) and two oblique. The four recti arise behind it by a continuous tendon at the bottom of the orbit, and pass forward, one above (*superior rectus*) and one below (*inferior rectus*). One on the outer side (*external rectus*) and one on the nasal side (*internal rectus*) are inserted by short mem-

branous tendons into the fore part of the sclerotic coat. The superior oblique arises from the bottom of the orbit, and passing forward, terminates in a tendon that passes through a cartilaginous ring or pulley, attached to the frontal bone, after which the tendon is reflected backward and downward to be inserted into the upper part of the sclerotic coat, midway between the cornea and the entrance of the optic nerve. The inferior oblique muscle arises at the lower and front portion of the orbit, passes backward and upward, ending in a tendinous expansion inserted under the external rectus at the outer and posterior part of the eyeball.

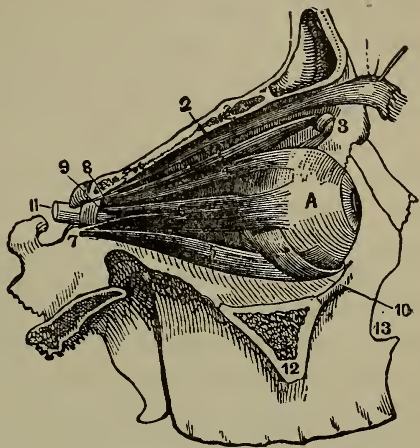


FIG. 161. — MUSCLES OF THE EYE.

A. Eyeball. 1. Levator palpebræ superioris. 2. Obliquus superior. 3. Fibro-cartilage ring or pulley of the obliquus superior. 4. Rectus superior muscle. 5. Rectus inferior. 6. Rectus externus. 7. Ligament of Zinn and origin of the lower head of rectus externus. 8. Upper head of rectus externus. 9. Internal for passage of the motor oculi and abducens nerves. 10. Obliquus inferior. 11. Optic nerve 12. Sphenoid sinus. 13. Nasal orifice.

The movements of the eye may be learned by a study of the table below: —

MOVEMENTS OF THE EYE.

Direction of Movement.	*By What Muscles Accomplished.*
Inward.	Internal rectus.
Outward.	External rectus.
Upward.	Superior rectus, inferior oblique.
Downward.	Inferior rectus, superior oblique.
Upward and downward.	Internal and superior rectus, inferior oblique.
Inward and downward.	Internal and inferior rectus, superior oblique.
Outward and upward.	External and superior rectus, inferior oblique.
Outward and downward.	External and inferior rectus, superior oblique.

THE OPTICAL APPARATUS.

For convenience of description we may consider the optical apparatus of the eye (Fig. 158) as made up of (1) a system of transparent refracting[1] surfaces and media by means of which images of external objects are formed on the retina; (2) a sensitive screen, the retina, capable of being stimulated by luminous objects and of sending through the optic nerve such impressions as to produce in the brain visual sensations; (3) an apparatus to turn the eyes in the same direction, making possible binocular vision; (4) an apparatus for focusing objects at different distances (*accommodation*); (5) means by which the amount of light received on the retina may be regulated. As an optical instrument the eye may be compared to a photographic camera.

The refracting media and surfaces of the eye are the anterior surface of the cornea, the posterior surface of the cornea, the aqueous humor, the anterior surface of the crys-

---

[1]In order that we may better understand the working of the eye in the formation of an image, let us briefly consider a few of the principles of optics by which images are formed. A single line of light is called a ray. A substance which permits the passage of light through it is called a medium. Media differ greatly in their power to transmit light, and thereby very materially affect the direction and velocity of the light which passes through them. When the ray strikes the medium at right angles, the principal effect is to decrease the velocity of the light; but when it strikes the surface obliquely, or the surface of the medium is curved, it changes the direction of the ray on entering the new medium, and thus bending (*refracting*) from its course is governed by the law that the ray in passing from a rarer to a denser medium, is bent toward the perpendicular to the plane of refraction; and if from a denser to a rarer medium, it is bent from the perpendicular. The angle which the incident ray (the one from the source of light) makes with the perpendicular of the refracting medium, as compared with the angle made by the refracted ray extending perpendicularly, is called the index of refraction, and is generally expressed by the ratio of sines of their angles.

When a ray of light enters a medium, it may be (1) bent from its course (*reflected*) (Fig. 163) by the resistance, of the medium; (2) on entering the medium, by its resistance it may be converted into heat (*absorbed*), and (3) it may pass through the medium, but be changed in its direction (*reflected*).

A lens is a transparent medium bounded by at least one curved surface. When the lens has one convex surface and one plane surface, it is called plano. convex; and when having two convex surfaces, double convex. To which of these does the cornea with the aqueous humor, with the iris and the crystalline lens, correspond?

talline lens, the substance of the lens, the posterior surface of the lens, and the vitreous humor.

From this it will be seen that there are five surfaces, and, including the air, five media. This would at first thought seem to make the refracting system very complicated, but for all practical purposes it may be reduced to a much simpler form — the cornea with its surfaces as one medium, the aqueous and vitreous humors as another, and the crystalline lens and its surface as another.

A careful study of Fig. 163 will make clear how the image is formed on the retina. Trace the pencil of rays represented by the diverging lines, and determine, if you can, why the image on the retina is inverted and smaller.

Determine from Diagram 163 the effect of shortening or lengthening the eyeball. From our experiments we have learned that the focus of rays is partially dependent upon the distance of the object from the lens. If then the retina of the eye should be in focus for a near object, it would be out of focus for distant objects.

The power to adapt the eye to see near and far objects is called *accommodation*. This power resides primarily in the crystalline lens, by its power to increase or decrease the convexity of its anterior surface, and thus change the focus. Study Fig. 163. Should the convexity be increased or decreased for viewing near objects when the eye is focused for a distant object? The amount of change for an object at a great distance and for one at the distance of four inches is only .143 of an inch.

The crystalline lens having no inherent power of contraction, changes in its form must be produced by power from without; this power is given by the ciliary muscles (*tensor choroidæ*). By its contraction the ciliary muscle draws forward the ciliary processes to which the capsule of the lens is attached; in this way the tension of the capsule is decreased, allowing the lens to become more convex. On the diminution or cessation of the action of the ciliary mus-

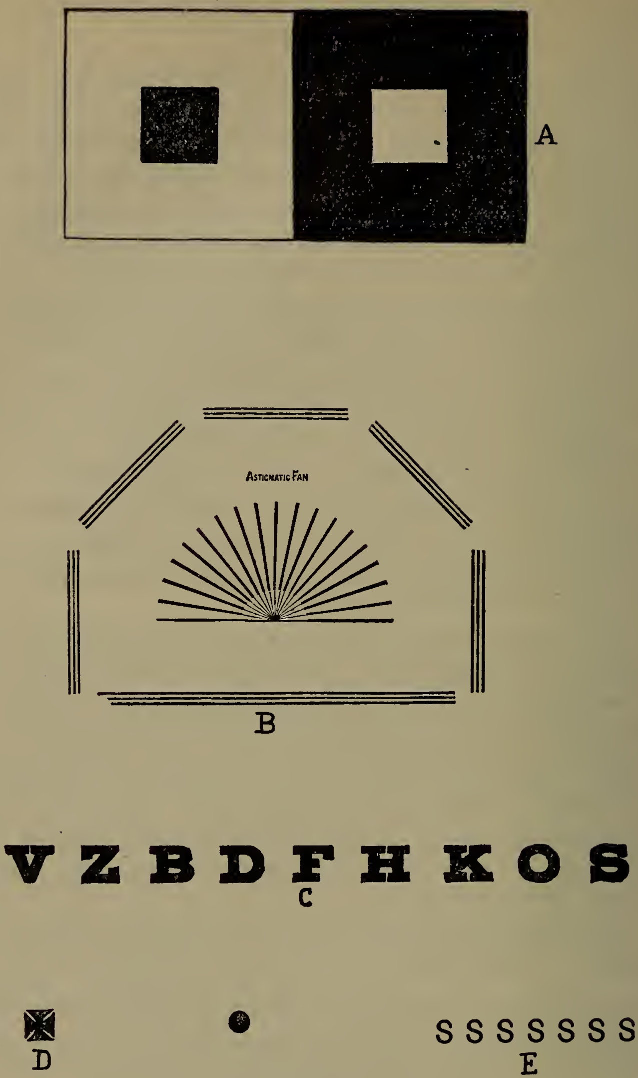


FIG. 162.

A. Irradiation.
B. Astigmatism.
C. Test type. Should be easily read by a normal eye at ten feet.
D. Test for the "Blind Spot."
E. Defective visual judgment. Look at object inverted.

cle the lens returns to its former shape by virtue of the elasticity of the ciliary processes. The eye is usually focused for distant objects, so the adjustments have to be made principally for near objects. There is a limit to the power of accommodation. This can be shown by bringing a book nearer and nearer to the eye, the words at last becoming indistinct from the lack of power of the lens to accommodate to the distance, and bring the light to a focus on the retina.

During accommodation there are two other marked changes which take place in the eyes: (1) the eyes converge by the action muscles of the eyeball (see table, page 403); (2) the pupils contract. Note that the contraction of all the muscles which are concerned with accommodation — viz., the ciliary muscles, the recti muscles, and the sphincter pupillæ — are under the control of the third nerve, but should the superior oblique be concerned in the movement of the eyeball, the fourth nerve is also concerned.

The limit of accommodation in the normal eye, for the near point, is four inches; for the remote point, an infinite distance. Owing to the lens becoming less elastic and the ciliary muscles weaker, the near point gets farther away as age advances. This defect in old people is called long-sight (presbyopia), due to the changed form of the eyeball.

Field of Vision.— By the visual field is meant that portion of the external world visible at one time. We can increase the field of vision by the movements of the eyes and those of the head. We generally use both eyes in looking at an object, and our normal vision is binocular. By a study of Fig. 163 it will be seen that the visual field of the left eye differs from that of the right eye. Not only is the image on the retina inverted, but also the position of the eye is changed; i. e., the left-hand side of the retinal image corresponds to the right-hand side of the visual field, and the right-hand side of the retina image corresponds to the left-hand side of the visual field. It will also be seen that in the right eye the right-hand side of the visual field corresponds to the nasal half (that part of the retina lying on the

side of the axis of the eye nearest the nose) of the retina, and the left-hand side of the visual field, to the temporal half (that part of the retina on the temporal side of the axis of the eye) of the retina; and in the left eye the right side of the visual field corresponds to the temporal half of the

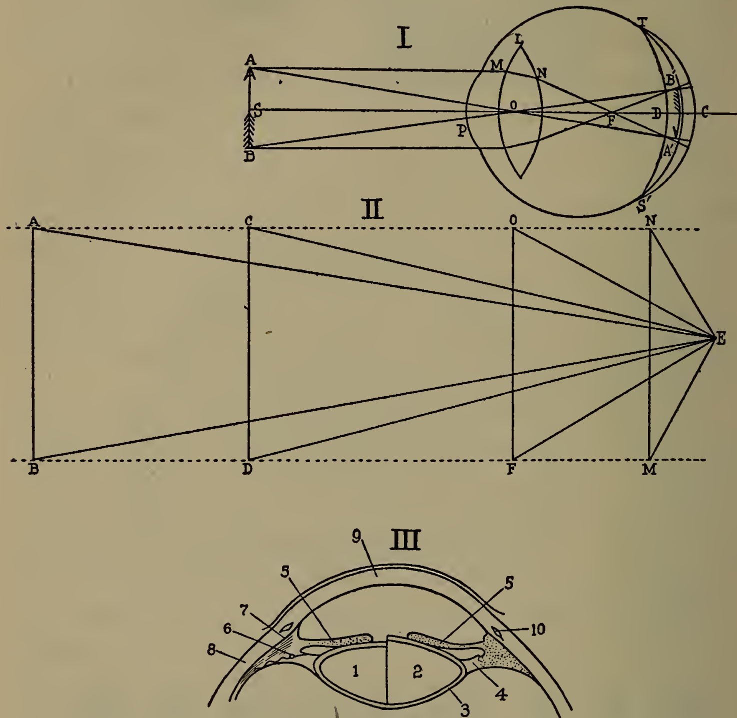


FIG. 163.—OPTICS OF VISION.

I. *How the Image Is Formed on the Retina.*
AB. Object. *A′B′*. Image of object. *AM*. Incident ray from *A*. *MN*. Refracted ray in lens. *NA′*. Refracted ray to retina. *AOA′*. Secondary axis focusing with *AMNA′* at *A′*. Notice how these lines cause the inversion of the image. *F*. Principal focus. *O*. Optical center of crystalline lens. *S′A′TP*. Form of the eye in normal vision (*emmetropic eye*). Notice the image is brought to a focus on the retina. *S′DTP*. Form of the eyeball in a long-sighted eye (*hypermetropic eye*). Notice the eyeball is too short, and the image is brought to a focus back of the retina. *S′CTP*. Form of the eyeball in a short-sighted eye (*myopic eye*). Notice the eyeball is too long and the rays come to a focus in front of the retina.

II. *Visual Angle.*
The objects at the points *BDF* and *M* respectively are of the same height, but that the angle formed by the lines that come from their extremities to the point *E* decreases with the distance; i. e., the visual angle decreases with the distance.

III. *Accommodation.*
If any eye is in focus for the rays *NE* and *ME* (Fig. II) from the extremities *MN*, it would not be in focus for the rays *AE* and *BE* from the extremities of the object *AB*. Notice the lens in the last case is more curved and thicker. 3. Capsule of crystalline lens. 4. Suspensory ligament. 5. Iris. 6. Ciliary processes. 7. Ciliary muscles. 8. Sclerotic coat. 9. Cornea. 10. Canal of Schlemm.

retina, and the left side to the nasal half of the retina. From a study of Fig. 163 it will be seen that if an object is brought too close to the eye, it will be seen by one eye only, and hence the vision is monocular, and in this case restricted to the nasal side. It will be noticed that the field of vision is greater for the two eyes than it would be for one, as a portion of the field is common to both.

In most cases the images of the objects looked at are small enough to be received by the corresponding points of the two foveæ, thus making the vision distinct, while those received outside of the foveæ are less distinct. Images not falling on the corresponding points, or imperfectly focused images, are not noticed, or at most, make a very weak impression on the brain.

Movements of the Iris.—The iris performs in the eye a function similar to that of the diaphragm of a camera, by

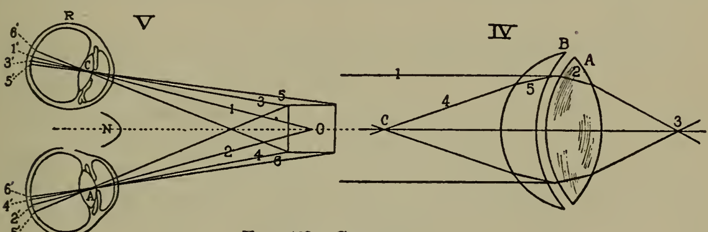


FIG. 163.—CONTINUED.

IV. *Diagram to Illustrate the Principle of Accommodation.*
A. Lens which focuses parallel rays at 3. 1, 2, 3. Course of a parallel ray from a distant object. *C.* A near object. *C* 5. An incident ray. If the object *C* is to be seen clearly, the rays from it must be focused at 3. To do this the rays before reaching the lens *A* must be made parallel. This is accomplished by the lens B and as they come at so different angle. We could not see the object *AB* as distinctly as that of *MN* if the refracting apparatus of the eye was unchangeable, unless we moved toward the object until the visual angle *AEB* was equal to that of *NEM*. If, however, we had some way by which tho rays from *A* and *B* could be more refracted, they might be focused on the retina, and we could see them clearly from the point *E*. This is accomplished by changing the curvature and thickness of the crystalline lens. 1. Form of crystalline lens in viewing object far away. 2. Form of crystalline lens in viewing near object in the eye by the thickness of the crystalline lens, which secures the same result by more highly refracting the incident ray.

V. *Binocular Vision.*
R. Right eye. *L.* Left eye. *O.* Object. *O* 1′. Axis of left eye. *O* 2′. Axis of right eye. *C.* Crystalline lens of right eye. *A.* Crystalline lens of right eye. *COA.* Optical angle. *N.* Ridge of the nose. 4 4′. Ray from anterior right corner. 3 3′. Ray from anterior left corner. Notice that each of these rays go to the nasal side of the axis of the eye. 5 *C* 5′. Ray from posterior left corner. 6 A 6′. Ray from posterior right corner. Notice that the posterior rays also to nasal side of the eye. 5 *A* 5′. Ray from anterior left corner to right eye. 6 *C* 6′. Ray from anterior right corner to the left eye. Notice that in the last two cases the rays go to the ear side (*auricular*) of the eye; also that the impressions made on the left eye differ from those made on the right eye, and that by combining these impressions we get the proper notion of the object and its perspective.

its contraction and relaxation increasing or decreasing the size of the pupil. As no light enters the eye except through the pupil, it serves to regulate the amount of light entering the eye. It also aids in correcting spherical aberration, and gives depth of focus.

Among the causes which produce the constriction of the pupil, are: (1) an increased intensity of light; the greater the intensity, the greater the constriction; (2) the viewing of near objects in order to give clearness by cutting off the widely divergent rays that could not be focused at the same point as the less divergent; (3) the turning inward of the eyes, as looking at a near object with both eyes; (4) the action of such drugs as opium, administered internally, or aconite; early stages of chloroform and alcoholic poisons; and the local application of eserin; (5) the division of the cervical sympathetic, or the stimulation of the third nerve; (6) sleep.

Dilation of the pupil is produced (1) by lessening the intensity of the light; (2) by looking at distant objects; (3) by an excess of aqueous humor, in difficult breathing (dyspnœa), or violent muscular effort, as in lifting heavy loads; (4) by the local application of atropine and its allied alkaloid, or by the internal administration of atropine and its allies; (5) in the last stages of chloroform and opium poisoning; (6) by paralysis of the third nerve; (7) by stimulation of the cervical sympathetic nerve.

BINOCULAR VISION.

Binocular Vision. — A single object forms an image on each retina, but we see but one object under normal conditions. By pressing the eyeball out of its usual shape, one object may appear as two. It appears that certain parts of each retina are so related to each other that when an image of an object falls on these at the same time the two sets of sensations excited in the two parts are blended into one. Such parts are called corresponding, or identical, parts, and the conditions of single vision with two eyes are that the

images from the various parts of the object fall upon the corresponding parts of the retina.

The spheres of the two retinæ may be considered as lying one over the other, as shown in Figures 163 and 164, the left portion of one eye lying over the identical left portion of the other, and so with the right; with the upper and lower portions of the two eyes, *a* lies over *a*, *b* over *b*, and *c* over *c*, and so with other points. If the axes of the eyes (Fig. 163) be so directed that they meet at *a* and *a*, the vision will be single, as the identical points will correspond.

The cause of the impression on the identical points of the two retinæ giving rise to but one sensation and to the perception of a single image, is difficult of explanation, and various theories have been proposed. It may be due to the structural organization of the deeper or cerebral portion of the visual apparatus, or may be the result of a mental operation; for in no other case is it the property of the corresponding nerves of the two sides of the body to refer their sensations as one to one spot.

The advantages of binocular vision are: (1) we get a larger field of vision than we could with one eye; (2) we can more accurately estimate the distance and size of objects; and (3) we have a clearer perception of depth or solidity, i. e., a better perspective.

Distance.— We cannot see distance, nor directly estimate it with the eye. Various visual sensations enter into our judgment of distance. With one eye we perceive distance very imperfectly (see Experiment 4). With but one eye we have but the sensation of the effect of accommodation; but with two eyes we have additional sensations, as the muscular efforts caused by the divergence of the eyes, the dissimilarity of the two retinal images, the clearness or haziness of the images, all of which serve as aids in our determining the distance of the object.

Size and Magnitude.—The estimation of size bears a close relation to the estimation of distance, inasmuch as our judgment of size depends mainly on the size of the

retinal image, and varies inversely as the distance. Touch aids us largely in learning real magnitude. The intervention of an object of known size, by which we may compare, aids much in determining the size of an unknown object.

Solidity.— Binocular vision is of especial importance in our notion of solidity. In looking at a solid object, there will be some points in the extreme left of the object that will appear in the image of the left eye and not in the right, and there will be some points in the extreme right of the object that will appear in the image of the right eye and not in the left. It is, perhaps, the blending of the impressions from these slightly dissimilar images in the two eyes that gives us the notion of solidity.

When an object is too far away for the dissimilar retinal images to be appreciated, the relief or solidity must be determined by other means, one of the most important of which is the distribution of light and shade on the surface. This is illustrated by what artists call modeling, as the distant mountain made by the gradation of the shades. The formation of a single form from two images by means of the stereoscope supports the theory that the images of two dissimilar pictures, differing much as retinal pictures do, leads to the perception of a single object in relief.

Color Vision and Color Blindness.[1]—When a ray of light falls on a prism, it forms what are called the rainbow colors, or spectrum. To persons whose color sense is normal, the spectrum presents the colors of red, orange, yellow, green, blue, indigo, and violet, shading insensibly into one another. In the spectrum formed by the sun there are black lines

---

[1] *Methods of Testing Color Blindness.*—Small skeins of colored wool are used, —red, orange, yellow, greenish yellow, blue, violet, purple, rose, brown, and gray. There are five finely graduated shades of each of the colors named. In testing a person, only one skein is used; e. g., a bright red. The skein being placed before him, he is asked to choose the skein most like the one he has.

By the experiments of Mace and Nacati, it was found that a red-blind person perceives green light much brighter than a normal person. The green-blind person had an excessive sensibility for red and violet. "It appears that what the color blind lose in perceptive power for one color, they gain for another."

passing through the spectrum which are designated by the line *a b c*, etc. While we cannot here discuss their cause, they will aid us in indicating position in the spectrum.

That we may better understand the nature of color vision, let us inquire as to the nature of light. We have many reasons for believing that light is caused by undulations, or waves, of ether, which pervade all space, even the interstices between the molecules of substances.

White light is due to the union of the waves of all visible frequency. (See Experiment 10.) Substances differ in their absorption power of light, some taking up nearly all the light, some but little, while others have absorption power only for certain kinds of light. The color of an object depends on the light it reflects. Transparent objects transmit all the light, as white; but colored transparent objects appear of the color of the light which they permit to pass.

From the experiments we have learned that colors may be mixed, producing white. Not only is this true of the colors of the spectrum, but it is also produced by certain pairs of colors called complementary colors, as red and greenish blue, yellow and indigo blue. White may also be produced by mixing red, green, and violet, which are known as fundamental, or primary, colors.

Each color is characterized by three qualities: (1) its hue; (2) its purity, or degree of freedom from admixture of white; and (3) the brightness, strength, or luminosity. Identical colors are those which possess these three qualities in the same degree, and appear as such to persons of normal vision. There are persons who do not have the power of distinguishing these three qualities in their true degree, and such persons are said to be color blind. The more common forms of color blindness are red blindness and green blindness. Persons thus affected are unable to distinguish between green and red. A person who is red blind regards certain hues of red as green and certain hues of green as white. To a green-blind person orange appears a pale red. By a study of the diagrams these defects may be studied more thoroughly.

Violet blindness is somewhat rare, and total color blindness very rare.

Most cases of color blindness are hereditary defects, and are incurable. Color blindness may also be produced by disease. Various theories have been given to explain color sensation, and of these the more satisfactory are those of Young and Helmholtz.

Young's theory (Fig. 165) is based on the fact that there are three fundamental colors, and from this, normal vision is considered trichromatic; i. e., that there are but three color sensations. This theory would demand but a few varieties of nerve endings to give us a knowledge of colors, but we can explain color sensation by having one set of nerve endings sensitive to red light, one to green light, and another to violet light.

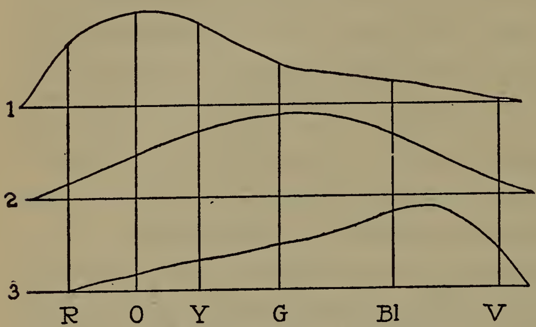


FIG. 165.—DIAGRAM OF THE THREE PRIMARY COLOR SENSATIONS (Young-Helmholtz Theory).

1. Red. 2. Green. 3. Violet. The letters indicate the colors of the spectrum; the height of the curve, the extent to which the several primary color sensations are excited by vibrations of different wave length. (C. W. B.)

We have by the modification of Helmholtz what is called the Young-Helmholtz Theory. This theory supposes that there are in the retina three kinds of nerve elements, each kind being most excitable or most affected by one of the three fundamental colors, but also in some degree by each of the other two. The combination of these primary sensations in varying proportion gives rise to the various colors just as in mixing the primary colors in varying proportions we get various colors. If the three sensations are of equal intensity, white light is perceived. This theory explains color blindness on the ground that in case of defect of the perception

of a given color some one of the fundamental elements is wanting, as for example in red blindness the fundamental red is wanting, and two fundamental sensations are wanting. It seems, however, that the parts are not entirely insensible to red, as red colors excite feebly nerve elements perceptive of green.

The theory also explains color after-images, as by staring at any bright object for a short time, the nerve perceptive of that color becomes fatigued, and the complementary color is seen on looking at a white background. While this theory helps us to explain many color sensations, it does not distinguish between retinal rest and the sensation of blackness, neither have we been able to find the three kinds of nerve endings which would make possible the three kinds of fundamental sensations.

DEFECTS OF THE EYE.

In the normal (*emmetropic*) eye, parallel rays are brought to a focus on the retina without the effort of accommodation. All objects over twenty feet away can be seen without any effort of accommodation; i. e., the far point of the normal eye is an infinite distance, and it is in viewing near objects that we have to call into use accommodation, in order to see the objects clearly.

The eye may be so constructed that rays from objects very near the eye are focused, while those from objects a short distance away are not, and the object becomes indistinct or is not seen at all. This condition is known as short-sightedness (*myopia*). The cause of this defect is an abnormal elongation of the eyeball, and quite frequently the eye is also larger, and probably the lens is more convex. As a result the rays are brought to a focus in front of the retina (Fig. 161), so that we have either a very indistinct image or none at all.

From our experiment you can easily understand how this can be overcome by the use of concave glasses. The opposite condition may also exist; the eyeball is too short, and as a result parallel rays are not brought to a focus when

they reach the retina. To focus parallel rays, an effort of accommodation is required, as from distant objects, and for far objects, very great effort is required. It will be seen from this that the ciliary muscles are constantly acting.

This condition is known as long-sight (Fig. 163) (*hypermetropia*). From our experiment, you can readily see why convex glasses are used to render the light more convergent, and thus correct the defect.

In order that the rays of light be properly focused, it is necessary that the lens have the same curve along all its meridians, for if less curved or greater curved along one meridian than along the other, it would make the ray at that part more or less divergent, and therefore an imperfect focusing of the rays, producing an imperfect image. In the eye, as a result of this defect, lines in one direction may be seen clearly, while those in another direction will be blurred. The eye may be myopic in one place, and hypermetropic in others. This defect is known as astigmatism, and is usually due to an unequal curvature of the cornea, but occasionally may be due to a defect of the crystalline lens. To correct the difficulty the glasses have to be especially ground, which requires great care on the part of the optician in his measurement.

The rays of light which fall upon the outer field of the lens are not brought to a focus at the same point as those which fall upon the central portion of the lens, owing to their unequal refraction. This defect is known as *spherical aberration.*

In a microscope, camera, and other optical instruments it is prevented by putting on the front of the lens a screen with a circular opening, so as to shut off the rays from the outer field, and allow only those to pass which are near the center. As has been suggested, the correction for aberration in the eye is made by the iris. The posterior part of the iris is covered with pigment to prevent the passage of light through its substance, thus shielding the light from all parts of the lens except parts back of the pupil.

The image will be best defined when the pupil is small and the amount of light is abundant, but the eye is so constructed that even when the pupil is much dilated, as in feeble light, the image may be quite well defined.

Distinctness of vision is further secured by the pigment of the outer surface of the retina and posterior surface of the ciliary processes. These pigments absorb any light that might be reflected within the eye, and prevent its being thrown again upon the retina to interfere with the image formed there. Were it not for this pigment, as the layer of the retina is very transparent, and if the opposite surfaces had the power of reflecting the rays, they would fall upon other parts of the membrane, producing both dazzling from excessive light, and indistinctness of the images.

When a ray of light is passed through a prism, it is not only refracted, but it is separated into its elementary colors. When a ray of light is passed through an ordinary convex lens, a similar separation of the light into its elementary colors takes place, giving to the images formed, colored margins. This is due to the difference in wave length of the different kinds of light; they are therefore refracted differently, and do not focus at the same point. This defect in optical instruments is called *chromatic aberration.* It is corrected in lenses by having them made of separate parts and different kinds of glass (as crown glass and flint glass), and so ground as to equalize the refraction of the different kinds of light, thus preventing a coloring of the image. Such lenses are called *achromatic.*

In the human eye this is probably overcome by the unequal refracting power of the refracting media in front of the retina. The eye is only achromatic when the image is received at its focal distance upon the retina, or so long as the eye has the power of accommodation. If either of these conditions be interfered with, more or less chromatic aberration appears. It is stated by Helmholtz that a small white object cannot be accurately focused on the retina; if we focus for the red rays, the violet are out of focus, and vice

versa; and when not exactly focused, they are seen surrounded by pale yellowish or bluish fringe.

Red rays being less refrangible, a stronger effort of accommodation is necessary to focus them, and the eye being adjusted as if for nearer objects, red surfaces appear nearer, while blue, requiring less effort (due to their greater refrangibility), appear farther away. From the imperfect adjustment of a small, white object it appears to be surrounded by a kind of halo. This appearance is called *irradiation.*

From the same cause a white square on a black ground appears larger than a black square of the same size on a white ground.

The long-sightedness of old age (*presbyopia*) is due to gradual loss of the power of accommodation, which is due chiefly to the gradual increased density of the lens, by which it is unable to become convex, and also to a weakening of the ciliary muscle and a general loss of elasticity of the parts.

Visual Sensations.— Light is the normal agent in excitation of the retina. The only layer of the retina capable of responding to this stimulus consists of the rods and cones. The following are some of the most important proofs of this statement: —

1. The point of entrance of the optic nerve has no rods or cones, and is insensitive to light.

2. The *fovea centralis of the macula lutea* is most sensitive to light, although it contains no optic nerve fibers. In the fovea, cones only are found, while in other parts of the retina rods are more numerous than cones.

3. The phenomena of Purkinje's figures are due to the shadows of the retinal vessels cast by the candle. The branches of these vessels are chiefly distributed to the nerve fibers and ganglionic layer; and since the light of the candle falls on the retinal vessels from in front, the shadow is cast behind them, and thus those elements of the retina which perceive the shadows, must lie behind the vessels. This seems to be a clear proof that the light-perceiving elements of the retina are not the fibers of the optic nerve forming the innermost layer of the retina, but the external layers of

the retina, rods, and cones, which appear to be special terminations of the nerve fibers.

Duration of Visual Sensation.— The duration of the sensation produced by a luminous impression is always greater than that of the impression which produced it. No matter how brief the impression, the effect on the retina lasts for about one eighth of a second. Thus a rotating stick when turned rapidly appears as a continuous circle. After a certain rate, the impressions, by their persistency, become fused in appearance. The after sensation of an impression varies directly as the intensity. As for example, looking at a bright object for some time, and then looking away, when the object may be perceived for some time.

Intensity of Visual Sensation.— It might seem at first thought that the intensity would vary as the intensity of the light. But this is not the case. Light must have a certain intensity before it can excite the retina, but it is impossible to fix an arbitrary limit to the power of excitability. The effect is not directly proportional to the increase of excitation, but it is, according to the law formulated by Fechner, as the *logarithm of the stimulus*. This law is only true within certain limits. When the retina is stimulated by the light of one candle, the light of two candles will produce a difference in sensation that will be distinctly felt. If, however, the first stimulus be that of an electric light, the addition of one candle would make no difference in the sensation. So if the first stimulus is small, a small increase will be noticed; but if the first stimulus be great, it will require a proportionally greater stimulus to be perceived. The stimulus increases as the ordinary numbers; the sensations, as the logarithm.

How the Retina Is Stimulated. — The method by which the retina [1] is stimulated, so that the visual sensation is per-

[1] The more important changes produced in the retina in vision are: —

1. Bleaching of the visual purple. This has also been found in the inner segments of the cones. The colored bodies (*chromophanus*) are represented as oil lobules of various colors: red (*rhodophan*), green (*chlorophan*), yellow (*xanthophan*). They are not found in mammals. The visual purple seems to be derived in some way from the retinal pigments, as it will not be formed if the retina be detached from the pigment layer.

ceived by the cerebrum, is not understood. It is thought that the light produces a chemical change in the protoplasm, and that this change stimulates the optic nerve ending.

Some light was thrown upon the nature of this change by the discovery of a temporary reddish-purple pigment (*rhodoplasm* or *visual purple*) of retinal rods. In experimenting on the frog it is found that the pigment disappears on exposure of the retina to the light, and reappears when the light is removed, and also that there are distinct changes in the visual purple when other than white light is used.

The visual purple is almost absent from the retinal cones, from the macula lutea, and from the fovea centralis of the human being, and it does not appear to exist at all in the retina of some animals, as the bat, dove, chicken, all of which have good vision. From this it seems that it is not essential to vision. While this is true, it is without doubt one of the changes important in reproducing vision.

Why the Object Is Seen Erect.—The retinal image is inverted. Why, then, do we see the object erect? The visual centers, like other centers, refer their impression to the exterior. This power is called *sense projection*. We do not say the sound is in the ear, but exterior to the ear from the sonorous body; the taste is not in the tongue, but in the sapid substance; and so with vision, the impression is not referred to the retinal image, but to the object that produced it, and as it is erect, the sense impression is the same. The fact is, we take no more conscious notice of the retinal image than we do of the changes which take place in rods of Corti in sound perception. The statement that we at first conceive of the object as inverted, and by acquired perception train ourselves to see objects erect, is untrue.

---

2. There is a movement of the pigment cells. When stimulated by light, the granules of the pigment cells which overlie the outer part of the rod and cone layer of the retina become diffused into the parts of the cells between rods and cones, the granules (*melanin*, or *fuscin granules*) passing down into the processes of the cells.

3. There is a movement of the cones, and it may be of the rods, too, on stimulation of the outer parts of the cones which, when not affected by the light, extend into the pigment layer, and are refracted. It is thought by some that this contraction is under control of the nervous system.

4. The researches of Dewar, McKendrick, and Holmgren give reason to believe that the stimulus of light produces a variation of natural electrical currents of the retina, which at first increase and then diminish. McKendrick thinks these electrical currents are the result of the chemical changes which we have mentioned as taking place in the retina.

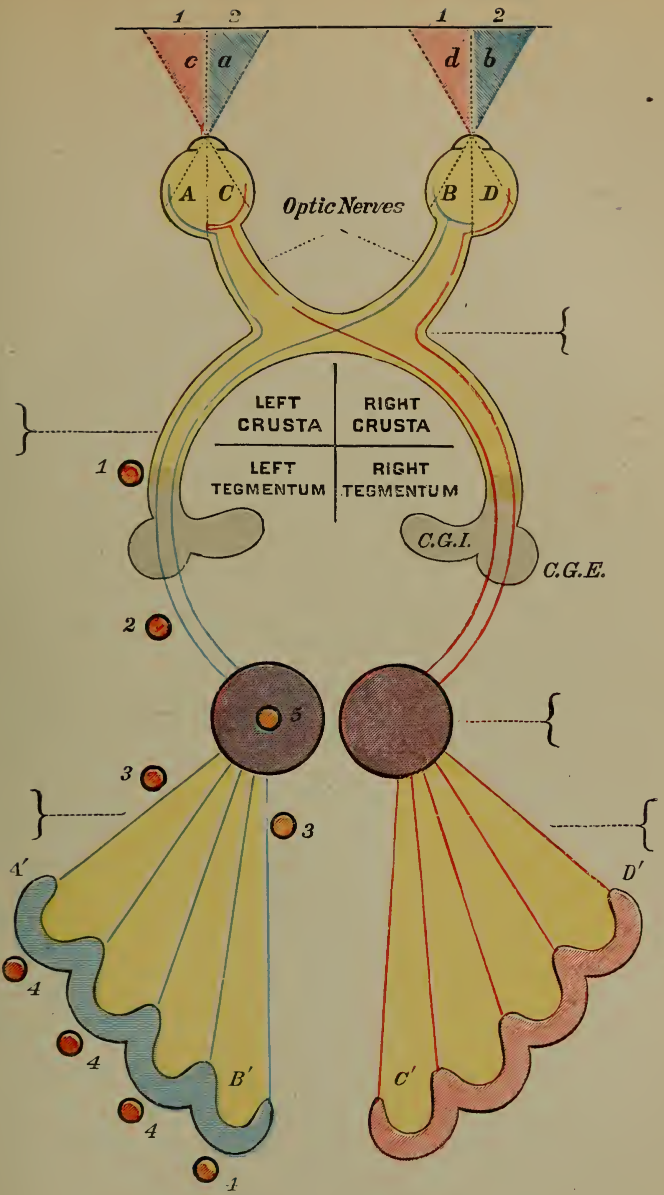


PLATE XVII.

Fig. 164.—A Diagram to Illustrate Nervous Apparatus of Vision in Man. (From Ranney.)

The lines (*A* and *B*) indicate the fibers associated with the left cerebral hemisphere. Those of the right hemisphere (*C* and *D*) appear as separate lines. Both will be seen in the diagram to pass from the retina through the following parts: the optic nerves; the crossing fibers through the optic chiasm, the optic tracts; the external geniculate body; the corpora quadrigemina or the "pulvinar" of the optic thalamus; and the internal capsule. The fibers are shown to end in the cortex of the occipital lobes.

A lesion situated at the points designated as 1, 2, 3, 4, and 5, will cause homonimous hemianopia. Lesions of the *right hemisphere* of the cerebrum produce blindness of the *right half* of each eye, and vice versa.

CHAPTER XIX.

HEARING.

EXPERIMENTS AND DEMONSTRATIONS.

1. Hold a watch between the teeth, or touch the upper incisors with a vibrating tuning-fork; close both ears by means of the finger. Do you hear the tick of the watch or the sound of the tuning-fork? Now unstop one ear. What difference do you note? How do you account for what you observe?

2. Hold the tuning-fork to the incisor teeth until you can no longer distinguish the sounds. Now close both ears. How do you account for the difference?

3. Listen to a tuning-fork set to vibrating by means of electricity, or to a watch ticking. Close the mouth and nostrils, and take a deep inspiration or deep expiration, so as to change the tension of the air in the tympanum. What difference do you note in the intensity of the sound? Explain the difference.

4. Suspend an iron poker by means of a string, wrap the end of the string so as to be about ten inches from the end of the poker, place the finger to which the string is attached in the ear, and strike the poker against a table or chair. Compare the sound made by striking it when the finger is not in the ear. What makes the difference? Also suspend a two- or three-pound weight by a stout string; tie free end around the finger so as to be two feet from the weight. Place the finger in the ear as before. Now strike the string, with the finger in the ear. Strike the string, with the finger out of the ear. What difference do you note? Explain difference. Vary length of the string. What effect has it on the pitch of the tone? Keeping the string of the same length, vary the weight. What effect has the increased tension?

5. Test a blindfolded person for his ability to judge of the direction of sound by snapping two coins together directly in front, directly behind, to the left, to the right, over the head, etc. Notice carefully the movements of the head.

6. Press both auricles against the side of the head, and hold both hands vertically in front of each meatus; have some one make a noise in front of you, and you will judge of the sound as coming from the opposite direction.

7. By examination of the outer ear, determine the names of its parts by comparison with Fig. 166.

8. Examine a model of the ear, and learn the parts by comparison with Fig. 166.

9. From the head of a rabbit or rat, saw out the portion of the temporal bone containing the ear for half of an inch on each side of the opening (*meatus auditorius externus*) to the ear. Put in different grades of alcohol as directed in the Appendix. When hardened, put in dilute acid for several days to remove the mineral matter of the bone. Wash thoroughly, and imbed in *celloidin*, and make section, mount in balsam, and examine. Examine some of the section with low-power lens (twenty to thirty diameters).

HEARING.— TEXT.

The organ of hearing is the ear. It consists of three parts: the external ear, the middle ear, and the internal ear.

The External Ear.— The external ear consists of two parts, the outer expanded portion, the *pinna* and the *canal,* or the *external meatus.* The pinna is composed of a thin plate of yellow cartilage covered by the skin, presenting eminences and depressions, the specific names of which may be learned from Fig. 166. The lobule of the pinna is free from cartilage. The pinna is united to the surrounding parts by ligaments and muscular tissues. The muscles of the ear are, one for raising the ear (*attollens aurem*), one drawing it forward and upward (*attrahens aurem*), one drawing it backward (*retrahens aurem*). In man these muscles have little action, but in some animals they are functional, and move the ear so as to direct its concavity in the direction of the sound, thus enabling the pinna to better collect the sound. The external meatus is about one and one fourth inches in length; its outer part is cartilaginous, its inner part bony. The skin in the deeper cartilaginous parts becomes more delicate and vascular, and contains a modified form of sweat

glands called *ceruminous glands,* which secrete a wax (*cerumen*).

The Middle Ear, Tympanum. — This is an irregular cavity (Fig. 166) in the temporal bone filled with air, received from the pharynx by means of a tube (*Eustachian tube*), which leads from it to the middle ear. The roof of

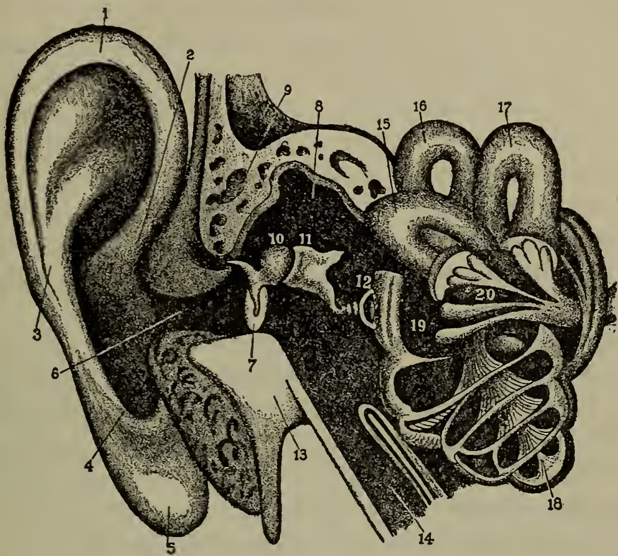


FIG. 166. — GENERAL VIEW OF THE EAR.

1. Helix. 2. Anti-helix. 3. Tragus. 4. Anti-tragus. 5. Lobule. 1, 2, 3, 4, and 5. Pinna. 6. Meatus (auditorius externus). 1, 2, 3, 4, 5, and 6. External. 7. Membrana tympani (drum of the ear). 8. Tympanum (middle ear). 9. Temporal bone. 10. Malleus. 11. Incus. 12. Stapes. 10, 11, 12. Bones (ossicles) of the middle ear. 13. Portion of temporal bone. 14. Eustachian tube. 15. External semicircular canal. 16. Posterior semicircular canal. 17. Superior semicircular canal. 18. Cochlea (turned down to show semicircular canals). 19. Vestibule. 20. Auditory nerve. (In the diagram the diameters of the middle and internal ear are larger in proportion to external than they should be; this is done to make the parts plainer. The cochlea is turned down to show the semicircular canals and auditory nerve.)

the middle ear, or the tympanum, as it is sometimes called, is formed by a thin plate of bone which separates it from the cranial cavity. Its floor is formed by a layer of the temporal bones. Its outer wall is formed by a membrane (*membrana tympani*), closing the meatus, composed on its outer part by the skin, and on the inner part by muscle fiber and mucous membrane, and also by the ring of bone to which the membrane is attached.

There are two small openings in the membrane for the exit of vessels and entrance of a nerve (the *chorda tympani*). This nerve is a branch of the seventh cranial nerve, and sends branches to the submaxillary glands and tongue. By some the branch which goes to the tongue is considered as the nerve of taste. The membrane of the tympanum is placed obliquely at the end of the external meatus. It is about one third of an inch in diameter. It bulges in somewhat, toward the tympanic cavity. To its inner surface is attached the handle of the mallet bone (*malleus*). On the outside, the drum of the ear is pressed on by the external air through the meatus, and on the inside by the air entering the tympanic cavity through the *Eustachian tube,* which ordinarily is closed; and if closed, any change in the pressure would lead to a bulging in or out of the membrane, as pressure is greater or less on the outside than on the inside.

The air pressure is kept equal by the Eustachian tube opening during every act of swallowing, admitting or letting out air as is needed to restore the equilibrium of pressure. The membrane being more or less on a tension, responds to the vibration of the air, and its peculiar structure and form enables it to receive tones of a great variety of pitch.

The inner wall of the tympanic cavity is osseous, except two apertures, which are closed by a membrane, one (*fenestra ovalis*) is connected with the vestibule of the inner ear, and the other (*fenestra rotunda*) is connected with the chochlea of the inner ear.

On the inner wall may be noted a bony prominence, the promontory between the two openings, a curved bony canal (*aqueducts Fallopii*), and a conical bone (*pyramid*) from which a muscle passes to the stapes. On the anterior wall is a canal containing the muscle (*tensor tympani*), which tightens the membrane, and is inserted in the upper part of the handle of the malleus.

On the anterior wall is the opening of the bony portion of the Eustachian canal. This canal, which is lined throughout with mucous membrane, and opens into the pharynx,

serves principally, as has been stated, to keep the pressure within and without the tympanum the same by the act of swallowing, which often takes place unconsciously, even when not eating. The entire tympanic cavity, as well as that of the Eustachian tube, is lined with mucous membrane, having ciliated cells. The ciliated cells, however, are not found on the tympanic membrane.

Bones of the Middle Ear.— A chain of three bones (*ossicles*) stretches across the tympanum from the membrana tympani to the fenestra ovalis. The first in the chain is the hammer (Fig. 166) (*malleus*). By its rounded head it articulates with the anvil, and by its vertical process or handle (*manubrium*) it is firmly attached to the fibrous layer of the membrana tympani, and to its inner and upper part is attached the tendon of the tensor tympani, by the contraction of which the handle is drawn, thus increasing the tension of the tympanic membrane. From the upper part of the handle passes a long slender process (*processus gracilis*) to a fissure in the bony wall, to which it is connected by ligamentous fibers. Another ligament also passes from the roof of the tympanum to the head of the malleus.

The second in the chain is the anvil (*incus*). In form it is more like a bicuspid tooth with widely separated fangs than like an anvil. The short process (*processus brevis*) lies horizontally, and is attached to the inner wall of the tympanum by a ligament. The longer process lies vertically parallel to the handle of the malleus, and is articulated to the stapes. The articulation between the head of the malleus and the body of the incus is of a peculiar saddle shape, the lower part of the articular surface of each bone having a blunt, tooth-like process, so that, when the hammer is drawn inward by the handle, it bites the anvil firmly, and carries it with it, but when the tympanic membrane with the hammer is driven outward, the anvil is not obliged to follow it. By this provision the stirrup is prevented from being pulled out of the fenestra ovalis by any undue push on the tympanic membrane. The lower end of the long process of the incus

bends inward, and ends in a small, flattened bone (*os orbiculare*) which articulates with the head of the stapes. In early years the os orbiculare is a separate bone, but it becomes joined to the incus in the adult.

The stirrup (*stapes*) lies horizontally at right angles to the long process of the incus, and its bony foot plate, covered internally with cartilage, is attached to the margin of the fenestra ovalis.

To the head of the stapes is inserted the small stapedius muscle, which arises from the inner tympanic wall through a hole near the fenestra ovalis. It is this muscle that regulates the movement of the stapes, preventing undue pressure on the labyrinth, and it may be considered as antagonistic to the tensor tympani.

The chain of bones thus formed is bound together and secured by ligaments, and may be regarded as a bent lever round an axis passing through the lower end of the neck of the malleus, the power being applied at the end of the handle of the malleus, and the effect being felt at the foot plate of the stapes; sound vibrations pressing in on the tympanic membrane press in on the handle of the malleus, causing its head, together with the body of the incus, to move outward, while the outward motion of the body of the incus causes its vertical process to have an inward movement that presses the base of the stapes into the fenestra ovalis against the liquid of the labyrinth. As the vertical process of the incus is only two-thirds the length of the first arm of the lever, the inward movement of the stapes will be only two-thirds that of the handle of the malleus, though the pressure exerted by the stapes will be one half greater. The area of the tympanic membrane is about twenty times that of the fenestra ovalis. This makes a relative large movement of small intensity by the tympanic membrane and chain of bones, one of smaller movement but of greater energy.

The Internal Ear.— The internal ear, or *labyrinth* (Fig. 166), is formed of tubes and cavities hollowed out in the temporal bone, and is inclosed on all sides, except openings of

the fenestra rotunda and the fenestra ovalis, on the exterior, and apertures for the branches of the auditory nerve and blood vessels on the interior. It consists (1) of the bony, or osseous, labyrinth formed in the petrous portion of the temporal, and (2) of the membranous labyrinth contained within the osseous labyrinth. Between the osseous labyrinth and the membranous labyrinth is a liquid called the *perilymph*, and

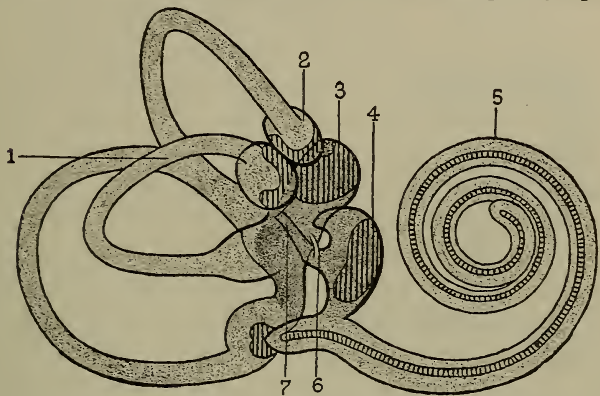


FIG. 167.—INTERNAL EAR.
1. Semicircular canals. 2. Ampulla. 3. Utricle. 4. Saccule. 5. Cochlea. 6. Duct of the utricle. 7. Endolymph duct.

within the membranous labyrinth is another liquid called the *endolymph.*

The bony labyrinth consists of three parts: 1. The *vestibule* is the central cavity, and has on its outer wall the fenestra ovalis, which is closed by the footplate of the stirrup bone, and also in its anterior wall is found the fenestra ovalis. On its inner walls are two depressions (*foveæ*), separated by a ridge. Behind it communicates by five openings with the semicircular canals, one orifice being common to two of the canals. 2. The semicircular canals, which are situated above and behind the vestibule, lie in three planes, one horizontal, two vertical, and at right angles to each other, like the three adjacent sides of a cube, the external horizontal canal opening by two distinct openings into the vestibule. The semicircular canals are about one twentieth of an inch in diameter, and end in a dilation at one end called the *am-*

pulla. 3. The cochlea is situated in front of the vestibule; in its form it resembles a small snail shell. Its parts are, a bony canal about one and one-half inches in length, and a central column called the modiolus, around which the canal winds spirally two and one-half times.

In the dry state the bony canal is partly divided into two canals by a thin bony plate (the *lamina spiralis*) projecting from the modiolus. In the fresh state there passes from the edge of the bony plate a membrane (the *basilar membrane*), which completely divides the coiled tube of the cochlea into two parts (*scalæ*), the upper one being called the stairway of the vestibule (*scala vestibuli*); as it starts from the vestibule, and winds around to the apex of the coil, the lower part is called the stairway of the tympanum, and is shut off from the tympanic branch by the membrane of the fenestra rotunda; it communicates with the upper space at the apex by a tiny hole (the *helicotrema*). A fine connective tissue membrane (*membrane of Reissner*) passing from the lamina spiralis to the bony wall of the cochlea forms in the small triangular part of the scala vestibuli a duct, called the central canal of the cochlea, or *scala media.* The bony tubular canal of the cochlea is thus divided into three canals (Fig. 168).

The Membranous Labyrinth. — The membranous labyrinth is a closed membranous tube, lined with epithelium and filled with endolymph, and having the same general form as the bony labyrinth in which it lies. The bony vestibule contains, however, two sacs, the utricle and the saccule. The membranous semicircle canals open into the utricle. They are adherent along one side of the bony canals, but are only one third the diameter of the bony canal. Each of the membranous canals is dilated when it opens into the utricle, the expanded portion being called the ampulla. There is no direct connection between the utricle and saccule, but they connect indirectly (by the *saccus endolymphaticus*), arising by an isolated limb from each sac, the limbs uniting in the form of a Y, the terminal sac lying in the skull. From the

membranous saccule a narrow tube (*the canalis reuniens*) leads into a small central canal (*scala media*) of the cochlea which is the cochlea portion of the membranous labyrinth and lies between the two scalæ.

By the system of canals just mentioned, the various parts of the membranous labyrinth are placed in communication, and thus the endolymph of one portion may mingle with that of another. Around the membranous labyrinth are the portions of the bony labyrinth not cut off by membrane and occupied by perilymph, the perilymph of the bony vestibule being continuous on the one hand with that in the bony semicircular canals, and on the other hand with that of the *scala vestibuli,* and through the *helicotrema* with that in the *scala tympani.*

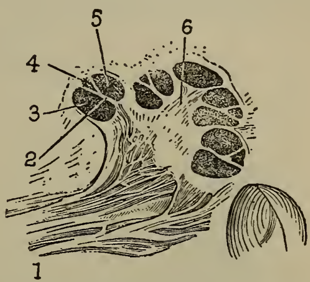


FIG. 168.—STRUCTURE OF COCHLEA. 1. Cochlear branch of the auditory nerve. 2. Lamina spiralis. 3. Scala tympani. 4. Ductus cochlearis. 5. Scala vestibuli. 6. Modiolus.

The Auditory Nerve.— This nerve enters the bony canal (the *meatus auditorius internus*) with the facial nerve and the nervous intermedius, and on leaving the bony canal, enters the labyrinth at the angle between the base of the cochlea and vestibule in two divisions, one for the vestibule and semicircular canal, and one for the cochlea; the branch going to the vestibule divides into two branches, one, the superior, distributed to the utricle and to the superior and horizontal semicircular canals, and the inferior, ending in the saccule and posterior semicircular canal. In both branches are numerous ganglionic nerve cells. The filaments derived from the cochlear branch of the auditory nerve pass up the axis of the cochlea, and give off fibers of the spinal lamina, at the base of which is the small spiral ganglion containing bipolar cells. From the edge of the spiral lamina the fibers pass to join with the organ of Corti (Fig. 169).

The Auditory Nerve Endings. — The membranous labyrinth is lined by an epithelium resting on a basis of connective tissue, the epithelium being modified in certain places to receive the nerve endings to form the nervous end organ of hearing. In the utricle the nerve fibrils are joined with an area of modified epithelium, forming an oval swelling (called the *macula acustica*); a similar area is found in the saccule. In each ampulla the epithelium is also modified where the

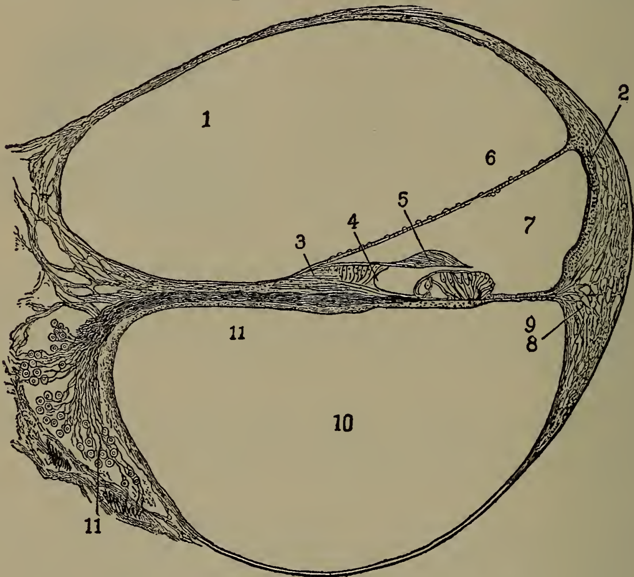


FIG. 169. — SECTION THROUGH ONE OF THE COILS OF THE COCHLEA.
1. Scala vestibuli. 2. Stria vascularis. 3. Limbus laminæ spiralis. 4. Sulsus spiralis. 5. Membrana tentoria. 6. Membrana vestibuli (Reissner's membrane). 7. Canal of the cochlea. 8. Basilar membrane. 9. Ligamentum spiralis. 10. Scala tympani. 11. Lamina spiralis (ossea).

fibers terminate, forming a horseshoe-shaped ridge (the *crista acustica*). The vestibular branch of the auditory nerve ends in the macula acustica of the utricle, the macula acustica of the saccule, and the crista of each of the three membranous ampullæ. In these various areas the modified epithelium is mainly formed of columnar cells, which end in a tapering process, called auditory hairs (Figs. 169), and to these hair cells of the maculæ and cristæ the naked axis-cylinders of the nerve pass, entering, according to some

authorities, the very substance of the cell itself. Between the columnar hair cells are a number of thin nucleated rod-like cells (*fiber cells*), which serve as a support. The free ends of the auditory hair are covered by a cap of mucous substance floating in the endolymph, and in the utricle and saccule this viscid endolymph contains small crystals, consisting principally of carbonate of lime, called *otoconia,* or *otoliths.* They probably serve as dampers.

The cochlear division of the auditory nerve passes into a small bony channel running up the modiolus, or the central column of the cochlea, giving off branches to the lamina spirals to be distributed as base axis-cylinders to the hair-like cells of the organ of Corti in the scala media. The floor of the spiral triangular tube of the cochlea is partly formed by the extremity of the spiral lamina and partly by the basilar membrane, which stretches from the end of the bony lamina to the outer wall of the cochlea, being attached to it by a structure of connective tissue called the spiral ligament. As the basilar membrane passes from the base to the apex of the cochlea it increases in breadth. It is composed of fibers which extend radially from within outward, and has on its upper surface, inside the central cochlear canal, modified epithelium, called the organ of Corti.

The Organ of Corti (Fig. 169) consists (1) of the rods of Corti, placed in about the middle of the organ. These are arranged along the spiral canal, in an inner and outer row, and consist of peculiarly modified epithelial cells, their bases resting apart on the basilar membranes, but their heads leaning against each other, like the rafters of a house. The series of arches thus formed by the two sets of rods forms a tunnel running along the length of the cochlear canal. The head of each rod gives off a process projecting outward, those of the inner row overlapping those of the outer, the inner rods, however, being one half more numerous than those of the outer rods, the heads of the two outer rods fit into three of those in the inner row, and when viewed from above by the microscope, the head plates of the rods of Corti resemble the

keyboard of a piano. (2) The inner hair cells, which are placed on the inner side of the inner rods, form a single columnar series, from the upper ends of which project a number of short auditory hairs, arranged in a crescent form, and their pointed bases rest among long nucleated cells, that appear to serve as supporting structure. (3) Those placed on the outer side of the outer rods, called the outer hair cells. They resemble the inner hair cells, having, like them, short hairs arranged in crescent form on the upper surface, and arranged, in man, in four rows. The supporting cells are on the outside of each of the outer hair cells, and are without hairs, and are called *cells of Deiters.* (4) Stretching like a network over the outer cells is a membrane called reticular membrane, composed of three series of fiddle-shaped rings united together by flat bars. The heads of the outer hair cells pass through the holes of the rings while the processes from the cells of Deiters are attached to the bars between the rings.

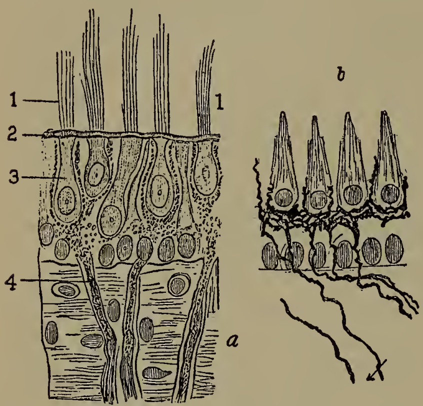


FIG. 170.—AUDITORY HAIRS.
1. Auditory hairs. 2. Limitans acusticæ. 3. Hair cells. 4. Nerve fibers.

A soft, elastic structure (*tectorial membrane*) that arises from the upper lip of the peculiarly formed piece of connective tissue, called the *limbus* at the edge of the bony spiral lamina (Fig. 168), overhangs the organ of Corti. By some authorities it is considered to be a damping apparatus for the organ of Corti.

The fibers of the cochlear nerve pass out from the spiral lamina after traversing the ganglionic bipolar cells of a small ganglion (*ganglion spirale*) situated in the bony lamina. On leaving the lower lip of connective tissue tipping

the spiral lamina they lose both their primitive and medullary sheaths, and pass as naked axis-cylinders to the hair cells. Most of the fibrils from these axis-cylinders do not appear to pass directly to the hair cells, but run some distance along the length of the cochlear canal in spiral strands at the base of the inner hair cells, or in the tunnel of Corti, or along the bases of the outer hair cells. Finally, however, the fibrils become connected with the hair cells, though there is doubt as to their passing into the cells, or perhaps they merely invest the cells. It is considered as settled that the inner and outer hair cells are the true terminal organs of the auditory nerve in which the sensory impulses that pass to the brain originate, and that the other parts of the organ of Corti are merely accessory in function, assisting in some way the nervous impulses, but not actually giving rise to them.

How We Hear.—The sound waves, which are collected by the pinna of the external ear, pass by the external meatus to the tympanic membrane, which is set in vibration, and, by its peculiar form and structure and being somewhat loosely and unequally stretched and loaded by the tympanic bones, is capable of taking up sonorous vibrations of various rates. These vibrations are transmitted onward by the chain of bones swinging as a whole and acting as a lever. With diminished amplitude, but increased force, the base of the stapes communicates the vibrations to the whole mass of perilymph in the vestibule, from which the vibrations pass along the scala vestibuli and down the scala tympani to end on the fenestra, the rotund membrane of which moves outward as the fenestra ovalis moves inward, and conversely.

As the vibrations pass up the *scala vestibuli,* they are also transmitted across the *membrane of Reissner* to the endolymph of the central cochlear canal and the basilar membrane, affecting in some way the auditory epithelium or hair cells of the organ of Corti, and thereby the terminations of the cochlear nerve. The vibration of the perilymph of the vestibule is also transmitted through the membranous

labyrinth to the endolymph of the utricle saccule and membranous semicircular canals, to reach the epithelium of the maculæ of the utricle and saccule and that of the cristæ of the ampullæ, affecting the terminal filaments of the vestibular nerve.

Vibrations may also be transmitted by the bones of the skull to the tympanic membrane, and onward by the chain of bones to the internal ear. The sound of a tuning fork may be heard by holding the fork between the teeth, the vibrations passing into the labyrinth through the bones of the skull, and affecting the auditory nerve, even when the tympanic membrane is injured.

The most highly specialized of the auditory apparatus is the *organ of Corti,* and it is therefore the chief agent in hearing. In order to understand more fully how we hear, let us give a more careful study of how the sonorous vibrations reach the hair cells of the organ of Corti.

A sound from a musical instrument or the human voice has a certain quality, or timbre, due to the blending of the fundamental tone (which determines the pitch) with the partial upper tones, which vary in number and intensity in different instruments. Thus the sound goes to the ear as a complex one. It is possible to analyze a composite sound by raising the dampers of a piano, and allowing the musical sound to be tested, to resound before it, when there will be a set of strings brought into sympathetic vibrations, that is, those strings which correspond in pitch to the fundamental tone and to the several upper tones of the note to be analyzed. Now suppose we were able to connect every string of a piano with a nervous fiber in such a manner that this fiber would be excited, and experienced a sensation every time the string vibrated. Then every musical tone which impinged on the instrument would excite (as we know really to be the case) in the ear a series of sensations exactly corresponding to the pendular vibration into which the original motion of the air had to be resolved. By this means, then, the existence of each partial tone

would be exactly so perceived as it is really perceived by the ear. But the ear has not the power of thus analyzing complex sounds, and cannot appreciate the pitch and qualities of tones; what part, then, of the auditory apparatus is it that is capable of being set into sympathetic vibration by the various complex waves of sound? It has not been long since it was thought that the rods of Corti, which vary regularly in the length and span of their arch from the base to the apex of the cochlea, served as an apparatus of sympathetic vibration for the analysis of sound, each pair vibrating in response to a particular simple tone, and stimulating a particular simple nerve fibril or group of nerve fibrils. But their number and variation in size and form do not meet the requirements for the wide range in pitch and quality of their capability of recognizing. In birds, that have without doubt appreciation of musical tones, there are no rods of Corti in their rudimentary cochlea, though hair cells lie in contact with the basilar membrane. It is now generally believed that the stretched radial fibers of the basilar membrane, on which the organs of Corti rest, are the vibrating threads which have the power of analyzing complex sounds; the rods of Corti assisting in the transmission of the vibration of the basilar membrane to the hair cells, and possibly acting as dampers, also, just as the chain of tympanic bones serves both purposes.

There are about twenty-four thousand fibers in the basilar membrane, their length varying from .075 mm. at the base to .126 mm. at the apex of the cochlea, and their tension probably being changed by the action of what appear to be muscular cells in the outer ligament of the membrane. It seems, then, that we have in this apparatus one that is adapted to appreciate pitch, and to the analysis of complex sounds. A single vibration reaching the ear excites by sympathetic vibration the fibers of the basilar membrane tune to the same pitch as the exciting sound, the shorter fibers near the base of the cochlea vibrating to the higher notes, the longer fibers of the apex of the cochlea vibrating to the lower

notes; and the different fibers tuned to difference of pitch affect in some way different auditory cells, which in their turn affect different nerve fibers, to give rise in the brain to different sensations of pitch.

In case of complex vibrations the basilar membrane resolves itself into its elements, one fiber taking up its fundamental tones and other fibers the various harmonies or partial tones, the synthesis of the sound as to its quality being affected in the nerve cells of the auditory center of the brain. While the theory just given is probably the most satisfactory, there are others which deserve consideration. One of the most important of these is the one which considers that sound waves on passing into the endolymph of the cochlear canal impress the *membrana tectoria,* and thus set in vibration the hair of the hair cells.

By those who hold the first theory given, the membrana tectoria is considered as a damper to check vibrations, the auditory hair serving to convey the damping action to the hair cells when excited in some other way. It is also probable that the organ of Corti has also the power to appreciate loudness as well as pitch and quality of tones. As noise has the properties of pitch and intensity, the sensory epithelium can also appreciate noise as well as musical tones.

As the sensory epithelium of the cochlea takes note of the intensity of pitch and quality of sound, it would seem that the sensory epithelium of the vestibular division of the nerve must have some other function than the perception of sound. It was formerly thought that semicircular canals were to aid us in determining the direction of a sound. But we have many reasons for not believing this to be their function. Their function is probably that of the sense of orientation, which enables us to determine our position in space, and, in connection with the sensation from the skin, muscles, and eyes, furnishes help in guiding in the complex co-ordinate movements by which the body is balanced and equilibrium is maintained. The varying pressure of the fluid endolymph in the semicircular canals gives rise to impulses

in the vestibular nerve endings of the ampullæ of these canals (*scalæ acusticæ*), producing sensations that enable us to become aware of the position of the body.

It will be noticed that the planes of the three canals lie in three axes of the spaces; a movement of the body or a change of the position of the head may lead to changes of pressure or movements of the endolymph that affect the ampullæ differently, and thus give rise to different impulses in the vestibular branch of the auditory nerve fibers distributed to the ampullæ. This theory would seem to be supported by the fact that injury to the membranous canals in birds and rabbits does not affect the hearing, but produces, especially in birds, some loss of co-ordination of movement with movement of the head in the plane of the injured canal and movement of the eyeballs.

Another evidence for this theory is that Menière's disease, the chief symptoms of which are giddiness and staggering, has been found to be associated with affection of the semicircular canals.

By some the sensory epithelium of the maculæ in the utricle and saccule has also been considered as connected with the sense of movement, and to have no connection with hearing. But there is doubt as to the truth of this statement, as there are animals low in the scale of organization that have a vestibular labyrinth without a cochlea, or with but a trace of one, that without doubt hear distinctly. In some crustaceans the organ of hearing is a mere spherical vesicle, partly lined by auditory hair cells, and some of these have been seen vibrating to sounds, the otoliths being forced down on the vibrating hairs to act as a damper when the sound was intense. It is not known, however, whether the vestibular nerve filaments of the utricles and saccule have the power to distinguish anything more than intensity. The fact is that the whole mechanism of hearing is far from being satisfactorily settled.

When the sensation of sound is produced in the mind, certain judgments respecting it form its conclusions by

knowledge previously acquired and by the aid of the other senses. Like visual sensations, which are referred not to the retina but to external objects, so the ear refers sound not to itself, but to something outside of the ear.

When the meatus (*auditorius*) is filled with water, the idea of the externality of the sound to the body disappears, and the sound that then reaches the tympanic membrane seems to originate in the head. The direction of sound is probably determined chiefly by the difference of intensity with which it is heard by each ear.

If the sound is directly behind, before us, or directly overhead, we are in doubt as to its direction until we turn the head to one side or the other. The determining of the distance from which a sound comes is largely an acquired perception, depending on previous experience of the quality of sound at various distances.

Anything, however, which prevents the sound varying normally (inversely as the square of the distance), as when the sound comes through a speaking tube, deceives us as to the direction, and causes us to judge of its being much nearer. The ventriloquist deceives by imitating the character of a distant sound; we thus judge it as far away, it being, however, near.

The slight difference between the intensity of the impression on the two ears does not give rise to the idea of two sounds, but we hear them as one, for they are in some way fused. The biaural audition in the normal mode of hearing aids us in our perception of space, but not in so high a degree as binocular vision.

CHAPTER XX.

THE VOICE.

EXPERIMENTS AND DEMONSTRATIONS.

Dissection of the Larynx.— Obtain from the butcher the larynx (Fig. 171) of a sheep or ox. It usually has the esophagus attached, and surrounded by a mass of muscle and connective tissue.

1. Slit the esophagus lengthwise, and turn it back so as to observe the opening (the *glottis*). Notice the lid-like cartilage (the *epiglottis*) which bounds it in front and at the sides by folds of the mucous membrane, and behind by the large converging yellow crests of the *arytenoid cartilage.* Notice that the mucous membrane of the larynx is continuous with that of the esophagus.

2. Cut away the esophagus, being careful not to cut the muscles of the larynx. Notice the prominent projection (*Adam's apple*) on the front part of the larynx. Trim away the muscles and other tissues from the front part of the larynx. Notice the cartilage (the *thyroid cartilage*) which forms the greater part of the larynx. Notice the relation of the muscles of the larynx to those of the esophagus. Notice the relation of the thyroid to the bone (*hyoid bone*) and the membrane (*thyro-hyoid*) which connects them.

3. Examine more carefully the nature and relation of the epiglottis. It is elastic. Press it down to see how it covers the glottis. What position does it take when released? Notice the muscle back of the upper angle of the thyroid cartilage and attached to the base of the epiglottis. Determine its function by pulling on it, and notice the effect produced by its shortening.

4. Notice the ring of cartilage (*cricoid cartilage*) below the thyroid marking. How do its anterior and posterior surfaces differ? How is it connected to the thyroid cartilage? Is the membrane muscular? In case of movement of these cartilages, where are their fixed points?

5. Notice the two curved yellowish cartilages (the *arytenoid cartilages*) projecting upward and backward from the top of the larynx. Are they movable? What relation do they bear to the cricoid cartilage? Determine what effect this movement backward and forward has upon the projecting ridges (*vocal cords*) which meet back of Adam's apple.

6. Examine the muscles which move the arytenoid cartilages: (*a*) One on each side of the posterior surface, the *cricoid,* which passes upward and is attached to the arytenoid of the same side. What effect would its contraction have on the arytenoid, and through the arytenoid on the vocal cords? Determine by dissecting it loose from the cricoid and pulling on the muscle. (*b*) The muscle (*lateral crico-arytenoid muscle*) arising from the upper edge of the lateral portion of the cricoid and passing upward and backward to the arytenoid. Determine its action by cutting it loose from its origin on the cricoid. (*c*) The broad muscle (*thyro-arytenoid muscle*) which arises along the whole length of the angle of the thyroid and joins to the arytenoid by converging fibers. By cutting it loose from below determine its action. (*d*) The muscle (*arytenoid muscle*) on the posterior surface of the arytenoid. What is its action?

7. Remove one of the arytenoid cartilages from its connection with the cricoid. How is it attached? How do you account for the synovia found at their articulation? Remove the muscle and other tissue so that you can study its shape more fully.

8. Remove the upper cartilage so as to expose the interior of the larynx.

9. Determine the interior of the larynx by cutting a specimen on the median line on the anterior surface. Examine another specimen from its anterior surface. How do the vocal cords seem to be formed?

10. Examine the larynx of some member of the class by means of a hand mirror or a laryngoscope. How do the position of the cords differ in high and low notes? What is their condition in breathing?

THE VOICE.—TEXT.

The Organ of Voice.— Speech is one of the crowning features which distinguishes man from the other animals, and gives him pre-eminence over all created existences.

The chief organ of this wonderful power is the larynx, which is situated at the upper and fore part of the neck between the large vessels of the neck, below the tongue and hyoid bone, and in front of the esophagus. It is composed of cartilage arranged into a funnel-shaped framework connected by elastic membranes or ligaments, two of which project into the cavity forming the vocal cords, these being more intimately connected with the production of the voice. The different cartilages are connected also by muscles, and have the power of movement one upon the other, and thus modify the form of the larynx and the tension of its ligaments. Its mucous membrane is continuous with that of the pharynx and with the trachea below.

Structure of the Larynx. — The larynx is composed of nine cartilages, three single ones and three pairs: Thyroid, cricoïd, epiglottis, two arytenoid, two cornicula larynges, two cuneiform.

The cornicula larynges and the cuneiform cartilages are very small. The large shield-shaped cartilage in form and at the sides is the *thyroid.* The ring-shaped cartilage below is the *cricoid.* The leaf-shaped cartilage above the opening (*glottis*) to the larynx, the epiglottis, and the hooked-shaped cartilage surmounting the cricoid, is the *arytenoid.* Carefully study Fig. 171.

The epiglottis is a plate of yellow fibro-cartilage, being attached by its narrow part to the interior of the thyroid cartilage at the front. It takes little or no part in the production of the voice. In swallowing it falls downward and backward, closing the glottis; at other times it stands upward, giving a free entrance to the larynx during respiration.

The thyroid (Fig. 172) is formed of two lateral halves, or wings, opened behind, but forming a ridge at an acute angle in front, the prominent point of which forms Adam's apple (*pomum Adami*).

Its sides, or wings (*alæ*), are quadrilateral in form, and have attached to their outer surface the *sterno-thyroid* and *thyro-hyoid muscles.* As we have said, the epiglottis is

attached to the inner surface of the thyroid at the angle and below the true and false vocal cords and thyro-arytenoid muscle. A membrane (*thyro-hyoid*) unites the upper edge of the thyroid to the hyoid bone, and it has below a membrane (*crico-thyroid*) connecting it in the front and on the sides by means of muscle (*crico-thyroid muscle*) to the cricoid cartilage. The posterior edge of the thyroid ends above and below in a prominent projection, or cornua, the inferior one articulating with the lateral surface of the cricoid cartilage.

The cricoid cartilage is situated below the thyroid, with its broadest part lying behind in the gap between the alæ of the thyroid and its narrow part in front, and joined to the thyroid by a membrane (*crico-thyroid*). By its lower border it is attached to the front ring of the trachea; its upper border at the highest part has on each side a smooth oval surface for articulation with the arytenoid cartilages.

The arytenoid cartilages resemble an irregular three-sided pyramid, and rest by their bases on the posterior and highest part of the cricoid cartilage, their apices turning backward and inward, and at their extremities surmounted by the two small cartilaginous nodules (*cornicula larynges*). From the anterior angles of the arytenoid the true vocal cords pass, to be attached in front to the thyroid in the angle between the lateral alæ (Fig. 171).

The true vocal cords are situated below the false vocal cords, and consist of two folds of mucous membrane inclosing and supported by fibrous tissue. The passages between the false vocal cords and the true cords are known as the ventricles of the larynx (Fig. 173), which leads into the vessels between the false vocal cords and the thyroid cartilages, called the pouches of the larynx (Fig. 173).

The opening between the true vocal cords is called the glottis or *rima glottis*. It passes horizontally from the arytenoid cartilage behind to the angle of the thyroid in front, in the male being less than an inch in length and more than a third of an inch when dilated. Its form, however, varies,

being widely open and somewhat triangular in quiet breathing, but in the production of different tones of the voice the fissures become narrowed, the inner margins of the arytenoid cartilages meet, and the free edges of the vocal cords approximate and become parallel, varying in their nearness and tension with the pitch of the tone produced (Fig. 174).

The muscles of the larynx may be learned by study of Plate XVIII.

The nerve supply of the larynx is derived from the superior laryngeal and inferior laryngeal branches of the vagus, the superior supplying the mucous membrane and crico-thyroid muscles of the larynx.

Voice and Speech. — The sounds of the human voice are produced by blasts of air, which set in vibration the true vocal cords.

The glottis during ordinary respiration is about half open, and widens slightly with each inspiration; with forced inspiration it becomes widely dilated, but, when vocalization takes place and the cords are set in vibration, the glottis becomes a mere chink with parallel sides.

By voice we mean the sound produced in the larynx by an expiration blast of air, setting in vibration the vocal cords. To produce voice the chink of the glottis must be narrowed by the free edges, and more or less nearly parallel, and the cords put on a more or less tension, the tension and approach of the cords being regulated by muscles, as shown in table, page 56. The loudness of the voice depends largely on the force of the expiratory blast affecting the tension of the cords.

In different voices the pitch depends upon (1) the length of the cords, varying as the length of the cord, the lower tones being produced by the long cords and the higher ones by the shorter cords. In women the vocal cords are one third shorter than in men, hence their voices are of a higher pitch. In most cases tenor singers have shorter cords than basses; sopranos, than contraltos. The change in the voice of males is due to the enlargement of the larynx and

the lengthening of the vocal cords, hence the deeper tones. The age at which the voice changes varies in different individuals, ranging from fifteen to nineteen years. (2) With the tension of the cords, the tighter the cords, the higher the pitch. Tones of various pitch may be produced by varying the tension of the vocal cords, as the muscles are brought under the control of the will. What is known as falsetto tones are thought to be produced either by the vibration of the edges of the cords only, or by the vibrating portion of the cords being shortened. The chest tones are produced by the vibration of the cords being communicated to the column of air in the resonant tubes above the larynx and in the trachea below.

Tones may have the same pitch, but differ very much in their quality. The property of a tone which enables us to distinguish it is known as quality or timbre. You may sound tones of the same pitch on a violin, piano, and flute, yet you easily recognize the tones of the different instruments; this is due to their timbre. We recognize the voices of our friends by their timbre.

Timbre depends principally upon overtones or harmonies which are produced at the same time as the fundamental. Thus when a bell is struck, the sound breaks up into portions or segments, one producing the fundamental, and the others the overtones, thus modifying the fundamental, giving as a result a complex tone and the characteristic tone or quality.

The quality may be due (1) to the nature of the vibrating substance; (2) to the overtones; (3) to the nature of the resonant body.

A voice sound seems to be very simple, yet, in reality, it is very complex, being made up of a fundamental tone and a number of accessory tones or harmonies, so that the audible tone produced in the larynx may be so affected in its passage through the adjustable resonant cavities and mouth, as to become speech. The quality of different voices is due to the different set of overtones that predominates; these being determined not only by the length and physical condition of

the cords, but also by the structure and form of the throat, mouth, and nasal passages.

Speech.— Speech is voice modified by alternations and additions made in the pharynx, mouth, and nose. The organs producing these modifications are called organs of speech. The teeth, tongue, and lips are called the organs of articulation. The sounds formed in the larynx are communicated to the air, and undergo modifications from the varying size of the cavities above and by the varying position of the tongue and lips, transforming the laryngeal sounds to articulate speech, consisting of syllables joined to form words. Speech may be produced without voice, as in whispering, where the sounds are produced in the mouth alone. The various sounds produced in speech are called elementary sounds, which are divided into vowels with consonants.

The vowels are the more open continuous tones. They differ only in the quality given to the tone by the overtones; they are re-enforced and modified in the cavity of the mouth and nasal passages, and they may all have the same pitch. The greatest modification is produced by the change in the form of the mouth. Helmholtz, by means of resonators, made an analysis of the vowels into their component vibration. He also succeeded in reproducing them synthetically.

Also note the form of the mouth and the position of the posterior part of the tongue in giving the vowels. Verify the following: (1) that in the production of the broad sound of *a,* as in *far,* the mouth is somewhat funnel shaped, with the wide part outward; (2) for *o,* as in *more,* it is like a little bottle with a wide neck; (3) for *o,* as in *poor,* the vocal chamber is large, with a narrow opening at the mouth; (4) for *e* and *i,* when having the sound of *eh* and *ee,* the mouth has the form of a bottle with a long and narrow neck, formed by raising the tongue toward the hard palate.

Diphthongs are produced by the mouth changing its form, as it would in passing from one vowel to the other.

The closer and less continuable sounds of speech are called consonants, and it should be borne in mind that there is no

sharp line of distinction between vowels and consonants, some of the most open consonants sometimes having the value of vowels.

Most of the consonants are produced by irregular vibration, having more of breath and less of tone than vowels, more like noise, less musical. In their production there is a narrowing of some part of the pharynx or mouth, which interrupts and modifies the air vibration from the larynx, or sets up other vibrations in particular parts. The consonants are divided, (1) as to the producing parts into labials, or lip letters, *p, b, v, m;* dentals, teeth letters, *t, d, th;* gutturals, or throat letters, which are made up at the top of the throat with the back of the tongue, *g;* (2) as to the degree of closeness or the mode of their production; into mutes, *b, p,* in which there is a complete shutting off the passages of the breath; aspirates, as *th, f, v, s, z,* in which there is a friction of the breath through the nearly closed passages; nasal, as *n, m, ng,* the breath being admitted through the nasal passages, and thus acquiring a peculiar resonance.

Stammering is produced by an irregular and spasmodic contraction of the diaphragm by which the expiratory bases of air upon which speech depends is interfered with. In some persons mental disturbance will produce stammering.

An inability to manage the larynx and other parts so as to form words produces stuttering.

APPENDIX.

I. HISTOLOGICAL METHODS AND REAGENTS.

Steps in the Preparation of a Permanent Mount.— In preparing a tissue for a permanent mount, the following steps are usually required: —

1. Killing.— By this is meant the destroying of the life of the tissue, which should be immediate, as gradual killing may bring about changes which modify very much the structure of the tissue.

2. Fixing.—This is so treating the tissue that its histological structure will be preserved, and decomposition will be prevented.

3. Staining.—The purpose of staining is to color the tissue so as to bring out more clearly its structure. Many tissues are so transparent that, without coloring, they appear structureless. The different parts of the tissue stain differently, and thus are more easily distinguished and studied.

4. Hardening.— Many of the tissues have to be cut into very thin sections in order to be studied to advantage; and to give the tissue firmness so that sections can be made, they are treated with reagents to harden them.

5. Imbedding.—The tissues which, after hardening, are not firm enough to be cut, are impregnated with a substance which makes them firm enough for section cutting.

6. Section Cutting.— This is usually done by means of an instrument called a microtome, by which the specimen is cut into very thin sections.

7. Mounting.—The sections are so treated that they can be put in dammar on the glass slip, and covered by a glass circle, and preserved.

The time required for these different processes and the reagents used will depend on the tissue. For most tissues the following will give good results: —

Killing and Fixing.—Three grades of *alcohol, 60, 70, and 80 per cent* respectively. Keep in 60-per-cent alcohol from 2 to 6 hours; in 70-per-cent, 3 to 8 hours; and in 80-

per-cent, 6 to 48 hours. The pieces of tissue, as a rule, should not be over three eighths of an inch on a side. When, however, this size does not include the size of the entire section of the part desired,— as that of the spinal cord, esophagus, or trachea,— the entire cross-section may be used; but it should be made thin—not over one eighth of an inch. When the tissue has become firm, it is ready for staining.

Staining. — Remove from the 80-per-cent alcohol to a solution of *picrocarmine* for 2 to 48 hours. The solution should be from eight to ten times the volume of the pieces to be stained, and put in a convenient-sized vessel. One-ounce slat-mouthed bottles are very convenient for holding staining and hardening solutions. The pieces should be removed from the staining solution as soon as they are colored through, which may be told by making a section of one of the pieces.

Hardening.—When thoroughly stained, remove the pieces from the staining solution, and place in *80-per-cent alcohol* from 2 to 6 hours. This will remove the excess of stain. When the tissue becomes firm, remove the pieces to *95-per-cent alcohol,* in which they should remain until quite firm (10 to 20 hours); then place for 15 hours or more in *absolute alcohol,* which removes all the water from the tissue.

Imbedding. —The object of imbedding is to filtrate the tissue with a substance which, when cold, will give to the tissue firmness, so that section may be made. The best material for most tissues is paraffin. Paraffin will not enter a tissue containing water, hence the importance of complete dehydration, as given under hardening. Paraffin is not soluble in alcohol; the alcohol must be removed by placing the pieces, when thoroughly hardened, in *spirits of turpentine* from 2 to 8 hours. If the pieces become very hard, or appear shrunken, they should be removed at once. As soon as the specimen becomes firm under pressure of the scalpel, remove to a saturated solution of *paraffin* and *spirits of turpentine.* To make the solution of paraffin, add to one ounce of spirits of turpentine heated to 45° to 60° C., small pieces of paraffin as long as it readily dissolves. When the solution is complete, remove the pieces from the spirits of turpentine, and put them in the paraffin solution, in which they should remain from 2 to 4 hours. The paraffin solution can be kept at the desired temperature by means of a water bath. Regulate

the flame of the burner so as to keep the temperature uniform. Melt the paraffin in a shallow vessel, and keep it one or two degrees above its melting point. Remove the pieces from the paraffin solution, and put them in the melted paraffin, in which they should remain from 2 to 4 hours.

Make two L-shaped pieces of lead one-half inch on cross-section, and one inch long by three fourths of an inch wide. Place the L-shaped pieces on a glass slip (2x2 in.), so that they will inclose a space three fourths of an inch square. Pour some of the melted paraffin into the space, and as quickly as possible remove one of the pieces from the bath, and put it in the melted paraffin of the molds. The pieces may be handled by means of forceps, which should be kept warm by keeping them, when not in use, on the water-bath. Put the glass slip and molds into cold water, so that the molds will be almost covered by the water, and as soon as the upper surface of the paraffin becomes hard, let the glass slip and molds drop into the water so as to immerse them. Leave them in the water until the paraffin is hardened. Remove from the water, and strike the edge of the slip against the table, which will release the molds. Remove the mold from the block of paraffin.

Section Cutting.— Cut off the end of the section, being careful to cut off only a very thin portion of the tissue imbedded. If the tissue is soft, it will not cut well; it should be firm, and show no signs of moisture. The paraffin block may be made to adhere by warming the receiver of the block, and gently pressing the end of the block against it, and then cool. Before cutting sections, the imbedding material should be cut away as much as possible from around the tissue, as it is easier to cut sections when the surface to cut is small than when it is large. The razor should be very sharp. Put under the microtome knife or razor a piece of paper to catch the sections as they are cut.

Mounting the Sections.— Clean thoroughly a glass slip. Place on the center of the slip, by means of a camel's-hair brush, a very thin film of a solution of collodion and clove oil (three parts collodion to one part of clove oil). Make the film as thin as possible. At once place on the film one of the thin sections. Gently heat over the alcohol flame until the paraffin is melted, and then immerse the section in a glass of spirits of turpentine. Leave in the turpentine until the

29

paraffin is dissolved. If the section is opaque on drying, it should be put back into turpentine, as the paraffin has not all been dissolved out. When the paraffin has all been dissolved, the section will be transparent. Wipe off the turpentine from around the section, and place on the section a drop of dammar or Canada balsam; clean thoroughly a glass circle or square, and put it on the drop of dammar. Press gently the cover to secure the spreading of the dammar. Place the slide away in a tray so that it will rest flatwise. Keep in the trays until the dammar is dry.

Other Methods.— *Use of Chloroform.*— Place the tissue to be imbedded in chloroform containing enough ether to keep the tissue from floating. Warm the tissue and chloroform to the melting point of the paraffin used, small pieces of paraffin being added during the warming. When bubbles are no longer given off from the object, the paraffin has displaced the chloroform, and the specimen is ready for imbedding by the same method as used for the turpentine. For nerve tissue, in embryological specimens, the chloroform method of infiltration is the best.

Staining on the Slide.— In this method the specimen is killed, fixed, and dehydrated as in the method given, the only difference being that it is not placed in the staining solution. It can be imbedded by either of the methods given, and sections made. Proceed as given above for mounting, except when the paraffin is dissolved out, wipe off as much of the turpentine as possible, and then add a few drops of alcohol, after which add a few drops of the staining solution. Let the staining solution remain on the section for ten or fifteen minutes, or until the section is well colored. Remove most of the staining solution by means of blotting paper, placed at the edges of the object; dehydrate by adding absolute alcohol. Remove excess of alcohol by means of blotting paper. Add a few drops of turpentine to remove the alcohol. Remove the excess of turpentine by means of blotting paper, then add a drop of dammar or Canada balsam, and put on cover glass.

Other Stains.— *Hœmatoxylin* is a better stain for nerve tissues than picrocarmine, and may be used as directed for the latter stain. If sections are stained too deep, the excess of stain may be removed by treatment with dilute hydrochloric acid until proper depth of stain is secured.

Methylene blue is of especial value as a stain for lymphoid tissues, lymphatic glands, and nerve tissues.

Examination of Blood. — Prepare slide as directed on page 167, Experiment 1; then treat the blood film with two or three drops of *Chenzynky's solution,* and let the solution dry. When dry, remove excess of stain by treating with two or three applications of alcohol. Add the alcohol by means of a pipette, and after one or two minutes, remove the alcohol with blotting paper. Repeat this treatment two or three times. Let the slide dry, then warm the slide to soften the ring of Brunswick black, and softly put on the cover glass. By this stain the red corpuscles will be colored red and the leucocytes, blue.

Biondi's Method. —"A drop or two of blood is mixed with 5 c.c. of osmic acid solution (as a rule it should be strong, 1 to 2 per cent), and allowed to remain in it from one to twenty-four hours."—*Lee.* Put a drop of solution on glass slip, let it dry, and color with picrocarmine.

Staining Micro-organisms. — *Koch's Method for Bacteria in Tissues.*—" Stain in aqueous solution of methyl violet, fuschin, or methyl-blue. Wash in a saturated solution of potassium carbonate diluted with an equal volume of water. The color will be removed from the nuclei of the cells, but remains in the bacteria; dehydrate, clear in cedar oil, and mount in balsam."— *Gould.*

Bacillus Tuberculosis.— Clean five or six cover glasses. Hold with the forceps each cover glass in the sputum so as to get a thin film on one surface of the glass; place on a clean glass square, so sputum side of cover glass will be up; cover with bell-jar, and let stand until dry. When dry, hold the glass covers in *Gibbe's double stain for bacillus* so as to have sputum side down and in the stain. Replace the cover glasses to the glass square, and let them dry as before. When dry, wash cover glasses in alcohol to remove the excess of stain and to dehydrate; let cover glass dry, and mount in balsam. Bacillus tuberculosis will be colored red; other bacilli, as well as the micrococci, blue.

Examination of Bone.— (1) *Without Decalcification.*— With a bone saw make as thin a section as possible; glue the section to one end of a cork, and file the section as thin as possible; smooth the section on a fine-grain hone-stone. Soak off the section from the cork by heating it in hot water; glue

the smooth side to the cork, and work down the rough side with the file and hone, making the section as thin as possible and of uniform thickness. Mount as directed on page 166, No. 34. Sections of teeth may be made in the same way. (2) *Decalcified Bone.*—Treat a small section of fresh bone with 95-per-cent alcohol for one or two hours, after which place the section into a ten-per-cent solution of nitric acid, which should be changed daily for eight or ten days. The section should be removed as soon as it is decalcified, as the acid will stain it yellow if left too long, or after the decalcification is complete. Remove the section, and wash for one or two hours in running water, and then place in 95-per-cent alcohol, in which it should be kept for a few days, when the alcohol should be changed. When dehydrated, section may be made, stained for five or ten minutes in a weak aqueous solution of eosin. "The ground substance and small cells of cartilage remain colorless; the nuclei of the large cells are stained red, and so is the periosteum, bone-tissue, and cellular contents of medullary spaces." Dehydrate section in absolute alcohol, and mount in benzol solution of Canada balsam. *Busch's method, Lee's Microtomist's Vade-Mecum.*

Warming the Slide.— In examining many live specimens, as the white corpuscles, it is necessary to keep the slide warm during the examination; this may be done by means of a triangular piece of sheet iron. The piece should be six inches long and one and a fourth inches wide at its widest portion. In the larger end there should be a hole three fourths of an inch in diameter. To warm the slide, place the larger end of the triangular piece so that the hole will be over the opening of the stage of the microscope. Put over this the slide to be examined, and clamp the slide down so as to hold the pieces in place, and place under the tapering end the flame of an alcohol lamp or Bunsen burner. If only a slight temperature is needed, put only the tip of the piece in the flame; if more heat is needed, bring the flame nearer the microscope.

To Clean Cover Glasses and Slides.— Leave cover glasses in dilute nitric acid for one hour or more, after which wash thoroughly in water, and let the glasses dry, where they will be free from dust. When they are dry, treat with benzole (*benzene*) or wood spirits (*methyl alcohol*). To remove balsam or dammar from slides, let them stay in spirits of tur-

pentine several hours, and then thoroughly wash in spirits of turpentine.

To Remove Covers from Balsam and Dammar Mounts. — Soak the mounts in spirits of turpentine for several days, until the dammar or balsam is softened, when the cover glasses may be removed by pushing the covers sidewise until they are removed from the slide. The covers and slides may then be cleaned as directed in the paragraph above.

Synthol.—This is a perfect substitute for alcohol, and may be used for all the purposes for which alcohol is used, except internal consumption. The author has given it a thorough test, and found it to be all that is claimed for it. It is equal to alcohol as killing, fixing, or hardening agent, and may be substituted for alcohol for making stains, reagents, etc. It has an advantage over formaldehyde, as it does not affect the eyes as the latter substance does. "As a preservative it is superior to any alcohol."

The author recommends its substitution for alcohol in the various experiments where alcohol is used.

Formaldehyde..—This is a good fixing and preserving agent. Tissues desired for examination can be preserved in it, and kept until needed for examination. If the specimens are to be handled with the hands, the specimens should first be washed in several changes of water. The pungent odor of formaldehyde may be counteracted by a few drops of ammonia.

BACTERIOLOGY.

Separation and Isolation of Bacteria. —When bacteria occur together, it is sometimes quite difficult to recognize them, even under high power. One of the first steps in the propagation of bacilli is isolation. This is done by using cultures, by means of which a particular species of bacillus is separated from other species, and its multiplication is favored. By this means they form into colonies, which may in most cases have a characteristic form or coloring by which they may be recognized even by the unaided eye. The identification thus becomes easy and certain. The bacilli may be separated by means of a platinum wire (No. 30), which is first sterilized by holding it in a Bunsen flame for a short time. Sterilize a test tube, and place in it 5 c.c.

of a sterilized culture medium. The tube may be sterilized by heating it to 20° C. in the air oven for fifteen or twenty minutes. To separate the bacilli, dip the platinum wire into the fluid containing the bacilli, and then place the wire into the culture. Plug the end of the tube with cotton that has been sterilized by heating it almost to the point of scorching. If the laboratory is not provided with a special apparatus for cultures, they may be kept at the proper temperature by means of a water bath or an incubator. The temperature required will vary with different bacilli. The culture should be carefully watched, and the changes carefully noted.

Kinds of Media Used for Culture.— The media used for culture are of two kinds, (1) liquid and (2) solid.

Liquid Media. — Until recent years the liquid media were exclusively used. The more important liquids used are, broth made from various meats, infusions of various vegetables, malts, solutions of yeast, solutions of various salts, with suitable proportions of sugar, peptone, or other organic substance added to give nutritive value to media.

Solid Media. —The more common solid media are slices of potato, hard-boiled egg, and broth, to which enough gelatin or agar-agar has been added to make the media solid at the temperature of the culture. In some cultures, like that of B. tuberculosis, solid blood serum is used. The more important advantages of solid media are, (1) that the organisms introduced into them are confined to the spot where they are placed, and around this spot the colony forms, not infecting the entire medium, as is the case with liquid media; (2) the obtaining pure cultures by Koch's method of *plate culture.* This method consists in taking a portion of the substance containing the micro-organisms, and thoroughly mixing them with some melted gelatin or agar-agar medium in a test tube, then pouring this mixture out on a horizontal plate, which on cooling forms a thin film on the plate. The plate is put in a moist place, and kept at the proper temperature, and in the course of a few days each organism introduced into the culture will have given rise to a separate and isolated colony, visible to the naked eye, and often presenting a very characteristic appearance when examined with a low power. Each of these colonies will be a pure culture, and fresh cultures may be made from them by inoculating new media.

This method presents the following advantages: (1) "It enables us to procure pure culture; (2) to test cultures supposed to be pure; (3) to ascertain the actual number of organisms present in a given quantity of substance; (4) to identify or differentiate between organisms, through the characteristic appearance of their colonies."

A Good Culture Medium.— Nutrient gelatin, most useful for the growth of all kinds of bacteria, is prepared in this way: —

"One pound of lean beef is cut up, to it is added one pint of water, and the whole kept boiling in the digester or any other vessel for from half to three quarters of an hour. After having been strained through fine calico, it is filtered through paper into a beaker. Bring up by adding water to 600 c.c.; add to this 60 grams of the finest gold-label gelatin, cut up in small pieces, 6 grams of peptone, and 6 grams of common salt. Dissolve in a water bath, but do not let the water boil; neutralize with carbonate of soda or, better, with liquor potassæ, till faintly alkaline; boil for half an hour, run through a hot filter into a sterile flask plugged with sterile cotton wool, and bring it up to boiling point, at which it is kept for a few minutes. This can be kept as a stock gelatin."—*Klein, "Micro-Organisms and Disease."*

Examination of Bacteria.— Place into each of several sterilized test tubes about 5 c.c. of the stock solution of gelatin, and make the following test: —

1. One tube unexposed to micro-organism and kept plugged with sterilized cotton.
2. One tube exposed to the atmosphere, and kept unplugged.
3. One tube exposed to the water from the hydrant, and after exposure kept plugged with sterilized cotton.
4. One tube exposed by placing in it a small amount of dust, and after exposure kept plugged with sterilized cotton.
5. One tube exposed to some milk, then plugged with sterilized cotton.
6. One tube exposed to pond water, or to an infusion of hay.

Label the tubes, place in a moist place, and keep them at a temperature of about 20° or 25° C.

Examine from time to time, and carefully note the changes.

In a similar way test other substances, as the secretions of the mouth, the material between the teeth, spoiled fruit, etc., the sputum of a healthy person, the sputum of a consumptive, and other material you may be able to secure.

Conditions Necessary for the Growth of Bacteria.— Procure some good culture, inoculate a number of tubes of media, and place them under different conditions of moisture, temperature, degrees of alkalinity and acidity, different degrees of saltness, with and without spices, with and without air.

Make a list of the favorable conditions, also those that are unfavorable, and those that destroy bacteria. How would you sterilize milk, water, fruits?

Cautions to be Observed in Handling Bacteria.— In handling pathogenic bacteria material, the greatest care should be exercised. Carefully observe the following: —

1. Do not handle the material with the bare hand, and sterilize all instruments immediately after use by leaving them for a few minutes in boiling water, or in a 30-per-cent solution of carbolic acid, or a .01-per-cent solution of corrosive sublimate for one hour. Never use formalin with steel or iron instruments. Never lay an instrument on the table after it has been contaminated with the infected material.

2. Be sure that there are no wounds or sores on the hands, and be careful not to wound the hands with instruments used.

3. After inoculating a culture, immediately sterilize the platinum wire used by holding it in a Bunsen flame for a short time. Never lay down the platinum wire without first sterilizing it.

4. After the inoculation of the cultures, destroy all infected material, either by burning or by thorough disinfection with corrosive sublimate or formalin.

5. Thoroughly disinfect all apparatus used.

Microscopic Examination of Bacteria. — Few if any of them can be examined satisfactorily under less than a one-twelfth-inch objective, and many of them require special staining and a one-twentieth-inch objective; still there are those which these powers do not define.

By means of the platinum loop, a small portion of the colony may be removed, placed on a cover glass, the material put under a desiccator, and let dry; color as directed with

methylene blue or any other stain desired, and stain as given in general method. If the media contain gelatin, it is best to complete the drying by carefully heating over the alcohol flame, only letting the flame come to the surface not coated with the media. After staining, wash out excess of stain by proper solvent (see methods given above). Dry, and mount in balsam. Use oil immersion lens.

When pure cultures have been made, good results may be secured with a one-eighth-inch objective dry lens, and in many cases with the one-sixth-inch objective; especially is this true of bacteria that have characteristic grouping.

Special Methods. — (1) *For Bacteria in Milk or Fatty Substances.*—" Dilute the milk with an equal quantity of water, or, in case of denser substances, with a larger volume. Spread on cover glass, and fix by heating. After it has become dry, stain for five minutes in twelve or fifteen drops of methyl blue to which three or four drops of chloroform have been added. Then remove, and allow the chloroform to evaporate; wash in water; mount."— *Ahren's Method.*

(2) *Preserving Sputum.*—"Let the patient expectorate into a receptacle containing 95-per-cent alcohol, in which the sputum may remain for several months, and in which it is hardened by dehydration and coagulation. A few drops of caustic potash solution added to a small lump of the hardened sputum on a slide will liquify it in a few minutes, and from this the cover-glass preparations are made. When dry, fix the film by passing the cover glass thrice through the flame of the spirit lamp, wash in water to remove the potash, and then stain according to any of the given methods."— *Savelieff's Method.*

THE MICROSCOPE.

The Simple Microscope. — Of the various forms of the simple microscope the *Barnes Dissecting Microscope* is the most convenient, as well as one of the cheapest. For teasing specimens and for examination requiring low power, this instrument should be used.

The Compound Microscope. —The parts of a compound microscope may be learned by a careful study of Fig. 175.

The Objectives. — For most of the work the two-thirds-

inch and one-sixth-inch objectives are most convenient. For determining the general structure of parts use the two-thirds

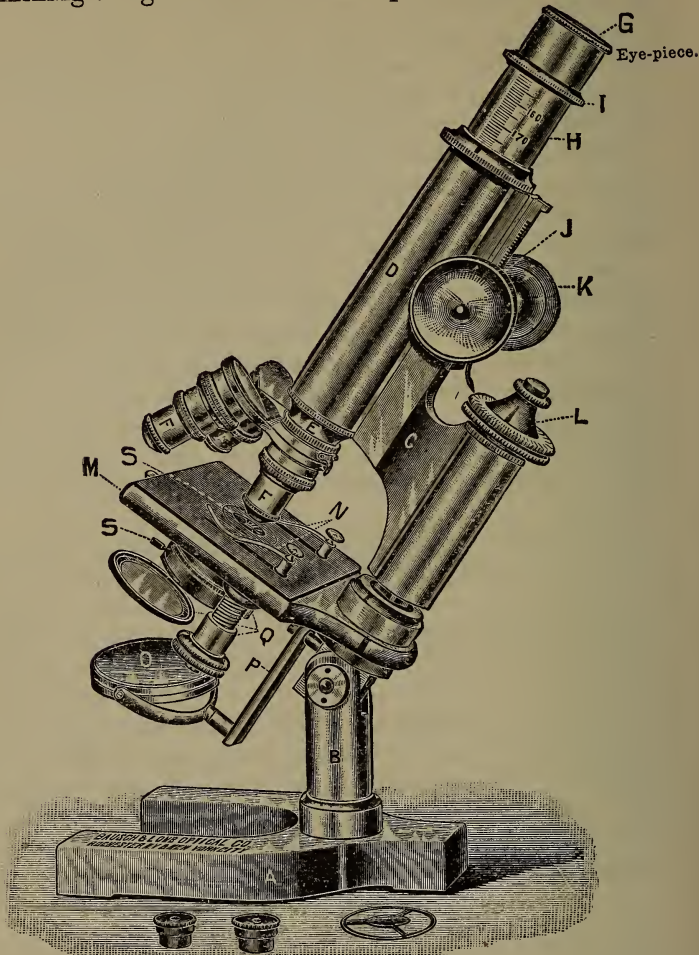


FIG. 175.—PARTS OF THE MICROSCOPE.

A. Horseshoe base. *B*. Pillar. *C*. Arm. *D*. Main tube or body, to the lower end of which the objective or revolving nose-piece is attached. *E*. Screw in lower end of main tube or body. *F*. Objective fit in nose-piece. *G*. Eye-piece. *H*. Draw-tube with scale for adjustment for length. *I*. Collar of draw tube. *J*. Coarse adjustment. *K*. Milled head of coarse adjustment. *L*. Milled head of fine adjustment. *M*. Stage. *N*. Spring clips for holding specimen. *O*. Mirror with plane and concave faces. *P*. Mirror bar. *Q*. Screw-substage. By the screw at the lift the substage may be adjusted or turned out of the way as desired. *S*. Iris diaphragm.

objective, but for examining any particular part more minutely, use the one-sixth objective.

In using the eyepieces, the two-inch eyepiece gives greater clearness, but less magnifying power, than the one-inch eyepiece. It should be kept in mind that as we increase the magnifying power, we lose light, and hence the need of special illumination for the higher powers. The mirror is for illuminating the object. The cone of light for illumination may be regulated by means of the diaphragm, the opening of which may be increased or decreased by the proper movement of the lever of the iris diaphragm. For the lower powers a large opening and the plane mirror should be used; for higher power, smaller opening and concave mirror. The size of the opening of the diaphragm should be inversely as the power; i. e., the higher the power, the smaller the opening of the diaphragm. *In using the condenser, always use the plane mirror.*

Focusing. — In examining a slide, be careful to have up the side on which the object is mounted, and bring the part of the object to be examined near the center of the stage so as to be in line with the objective and eyepiece. If a two-thirds objective is used, bring the objective to within one half inch of the surface of the slide. To do this, turn down the rack and pinion adjustment (the *coarse adjustment*). Look through the microscope at the object, and gradually turn the coarse adjustment toward you until the object comes in view; bring the object to a clearer view by means of a few turns of the *fine adjustment*. In using the one-sixth objective, the objective should be brought very near the surface of the object, but being careful not to touch the cover glass; focus by turning the coarse adjustment toward you.

Finding the Object. —The best method is to get the part of the object to be examined in the center of the field of the microscope by examination with the two-thirds objective; then reverse the objectives, and examine with the one-sixth or one-eighth as desired. In working with the slide to bring it into position, remember that the image on the microscope is inverted, and hence the movements are the opposite of what they appear to be when looking through the microscope; i. e., if we desire to have the object appear to move to the right in the microscope, it should be moved to the left; to move up, it should be moved down.

The Oil Immersion. — For objectives higher than one-eighth, oil immersion lenses should be used. To use the oil

immersion lens, bring the object desired for examination into focus by means of the one-sixth objective. If the microscope does not have a triple arm nosepiece, replace the one-sixth objective by the one-twelfth or the one-sixteenth oil immersion objective. Place over the object to be examined a drop of the immersion oil, and bring, by means of the coarse adjustment, the objective in contact with the surface of the object; turn the substage condenser so as to bring it under the object; illuminate the condenser by the plane mirror, and adjust the mirror and condenser so as to condense the light on the object. Gradually focus toward you by the coarse adjustment. For clearer definition use the fine adjustment.

The Joint.—The purpose of the joint is to enable the tube of the microscope to be bent at a convenient angle for observation. To incline the stand, always grasp it by the pillar, and never by the tube.

CARE OF THE MICROSCOPE.

1. Keep it protected from the dust as much as possible, and when not in use, keep it covered with glass bell-jar or some other suitable cover. If dust collects on the instrument, remove it first with a camel's-hair brush, and then wipe carefully with chamois skin.

2. Never wash the parts of the microscope with alcohol, and under no conditions use alcohol on the objectives or eyepieces.

3. Let no one except those who have been instructed in the use of the microscope, handle the microscope or the accessories.

4. Avoid exposure of the microscope to direct sunlight or to extremes of temperature.

5. When handling the stand, grasp it by the pillar or stage. While the arm is the most convenient part, it is also the most dangerous part to the fine adjustment.

6. Always handle the instrument with great care, and avoid any sudden jars to the instrument.

7. Remove Canada balsam and like substance with a cloth moistened with benzole, and then wipe dry.

8. If the pinion works loose, tighten by the screws on the pinion covers.

9. Never use a common screw driver in setting the screws of the instrument, but one with parallel sides, and which just fits the slot of the screw.

10. *Care of Objectives and Eyepieces.*—They should be kept from extremes of temperature. If dust collects on them, it should be first removed with a camel's-hair brush, and then by rubbing with a chamois skin. Never use a chamois skin until it has been washed several times. To determine if the dust is on the eyepiece or the objective, rotate the eyepiece, and if on the latter, the spots of dirt will move with it, but if on the objective the spot will not change position by the rotation of eyepiece. Never touch the glass of the objective or eyepiece with the fingers. To clean the surfaces, breath upon them, and wipe dry with clean linen cloth. If lint adheres to the glass, it may be removed with a camel's-hair brush, or by blowing upon the surface. Always clean an immersion lens immediately after use. Remove the fluid with moist cloth, and wipe clean with dry cloth or lens paper.

II. GENERAL RULES FOR DISSECTION.

Preparing the Specimen.— For the most part the specimens required for the work of this book may be obtained of a butcher, and such parts only as are needed for the work in view need be taken to the class or put in the hands of the pupils. As far as possible, remove from the specimen all unnecessary parts, so that the whole attention may be directed to the subject under consideration.

Killing Animals for Dissection.— In dissection for school work do not use the cat or dog; use instead a rabbit or rat, as these will not offend the finer feelings which pupils have for the domestic animals. In college work there is no objection to the use of the cat or dog, provided these are secured with the consent of the owners. In all the work avoid any signs of cruelty. The killing of the animal should be as painless as possible, and conducted so that there will be no injury to the tissues of the animal. If you do not have an anæsthetic box, a box of sufficient size to cover the animal will do. Place a newspaper on the floor or table, and invert over it the box. Put the animal under the box, and pour 10 or 15 c.c. of chloroform on a sponge or a piece of cotton as large as your fist, and put it under the box with the animal, keeping the box closed. Have a good draft in the room, and avoid breathing the chloroform. As the animal comes under the influence of the chloroform, there will be more or less of a struggle, and it will be necessary to hold the box down, or

put a heavy weight on it. From ten to twenty minutes will be required to kill the animal. If you do not notice signs of sleeping in five or ten minutes, the dose of chloroform may be repeated. Do not dissect the animal until all signs of life have disappeared. The amount of chloroform required to kill an animal varies with the size and nature of the animal and the tightness of the box used. Turtles require a very large amount. After the animal is killed, parasites that may be on the animal may be killed by benzine. This should be put on the sponge the same as the chloroform, and placed under the box with the animal, and kept there for ten or fifteen minutes, which in most cases will kill the parasites.

A good-sized dissecting board should be used, so as to avoid staining or injuring the table. The four corners of the board should be provided with screw-eyes or hooks, so that the limbs of the animal may be tied firmly in their place while dissecting. Plenty of sponges and absorbent cotton should be provided. All the waste parts should be thrown in the waste pail. Charcoal, potassium permanganate (a saturated solution), and sulphate of iron, or formalin, may be used to deodorize the pails and the animal for dissection. Of these, formalin (formaldehyde) is to be preferred for convenience and economy.

Dissection Wounds. — Care should be taken not to wound the hand with the dissecting instruments or by sharp points of bones, especially if the animal has been killed some time. If you are to handle specimens of animals that have been killed for some time, before beginning the dissection it is best to rub the hands with carbolated vaseline. This will prevent the absorption of any poisonous material which may exist in the specimen. Never dissect if the skin of the hand is broken, if the specimen has been killed some time, or putrefaction has set in. If wounds should occur during dissection, they should be treated at once with strong carbolic or nitric acid.

After dissecting, the instruments used should be thoroughly cleaned, and sterilized with a thirty-per-cent solution of carbolic acid.

The waste from the dissection should be thrown into the furnace, and burned; or if thrown out, should first be treated with a solution of corrosive sublimate, and thrown where it will not contaminate the water or the air.

III. TABLE OF TESTS.

TEST.	REAGENT.	REACTION.	APPLICATION AND REMARKS.
Acids: — Acetic.	Ferric chloride.	Dark red solution; on boiling gives a brownish precipitate.	Add the acid to be tested to a solution of ferric chloride, and boil. The acid has the odor of vinegar.
Arsenic.	Copper sulphate and ammonium hydroxide.	Apple green precipitate of arsenic is present.	Add to a solution of copper sulphate a few drops of ammonia hydroxide and to this the substance to be tested.
	Hydrogen sulphide.	Light yellow precipitate.	Pass hydrogen sulphide gas into a solution of the supposed arsenic compound. To dissolve arsenic add it to a solution of caustic soda.
Alkalies.	Phenopthalin.	Red solution.	Add reagent to substance.
Carbolic.	Red litmus paper. Sulphuric acid and potassium nitrate.	Blue. Violet color or streaks to the solution.	Test substance with the paper. To 2 c.c. of sulphuric acid add an equal amount of acid to be tested and a small amount of the potassium nitrate. (*Hoffmann's test.*) Characteristic odor.
Chromic.	Alcohol and sulphuric acid.	Green color to solution and forming aldehyde, having the odor of squash bug or chinch bug.	Add a few drops of sulphuric acid to a strong solution of the acid to be tested, and then add the alcohol drop by drop, and note change.
	Ethereal solution of hydrogen dioxide.	Intensely blue color.	Add the reagent to solution of the acid. (*Storer's test.*)

TEST.	REAGENT.	REACTION.	APPLICATION AND REMARKS.
Citric.	Ammonia.	Yellow color.	Heat the ammonia with the citric acid in a sealed tube to 120° C. for six hours. Heat in air-bath. Blue when poured out and allowed to stand. (*Sabanin and Laskowski's test.*)
Hydrochloric.	Silver nitrate.	White precipitate.	Add solution of the silver nitrate to the acid.
Hydrocyanic.	Yellow ammonium sulphide and ferric chloride.	Deep blood-red solution.	Add the ammonium sulphide to the solution of the acid; boil to remove excess of the ammonium sulphide, add a drop or two of the ferric chloride solution.
Lactic.	Bismuth hydroxide and alcohol.	White, brittle, horn-like mass precipitate.	Neutralize a dilute solution of the acid with freshly precipitated bismuth hydroxide, and add alcohol to precipitate the salt thus formed.
Nitric.	Bits of copper.	Red fumes and green solution.	Add the acid to bits of copper.
Oxalic.	Lime water.	A white precipitate.	Add the solution to the lime water.
Phosphoric.	Ammonium chloride, ammonium hydroxide, and magnesium sulphate.	White crystalline precipitate.	Add the ammonium chloride, the ammonium hydroxide, and then the magnesium sulphate.
Pyrogallic.	Ammonium hydroxide.	Lemon yellow solution.	Add the ammonia to a solution of acid to be tested.
	Nitrate of silver and sodium carbonate.	Black precipitate.	Add the carbonate to the solution to be tested, and then the silver nitrate. The acid stains the skin brown.

TEST.	REAGENT.	REACTION.	APPLICATION AND REMARKS.
Sulphuric.	Barium chloride.	White precipitate.	Add a solution of the barium chloride to the acid to be tested. If you do not have barium chloride, use lead acetate, which also gives a white precipitate.
Tannic.	Solution of ferric chloride.	Black precipitate and solution.	Add the ferric chloride to the acid to be tested.
Tartaric.	Solution of ferrous sulphate, hydrogen dioxide, and sodium hydroxide.	Violet colored solution.	Add the reagents to the acid to be tested.
Uric.	Nitric acid and ammonia.	Beautiful red color.	Cover the substance with nitric acid and evaporate to dryness on water-bath; add the ammonia. (*Murexid test.*)
Alcohol:— Methyl.	Fats.	Dissolves.	Odor. Boiling 66° C. Specific gravity, .796.
Ethyl.	Potassium dichromate and sulphuric acid.	Green mass and an aldehyde having odor of squash bug.	Powder the dichromate, and add the sulphuric acid, then the alcohol.
Absolute.	Dried ferrous sulphate.	Should remain colorless; change to light green shows the presence of water.	Add the alcohol to the dry salt.
Alum.	Ammonium, chloride, and ammonia hydroxide.	Gelatinous precipitate.	To the solution of the alum add solutions of the reagents in the order named.
Albumin.	Ammonia and nitric acid.	Yellow precipitate.	Boil the solution of the albumin, and add the nitric acid, then the ammonia.
Ammonia.	Hydrochloric acid.	White fumes.	Put the hydrochloric acid in one test-tube and the liquid to be tested in another, bringing the mouths of the tubes together.
	Copper sulphate solution.	Deep blue solution.	Add a few drops of solution to be tested to the copper sulphate solution.

TEST.	REAGENT.	REACTION.	APPLICATION AND REMARKS.
Antimony.	Water.	Curdy precipitate.	Add the antimony chloride to the water.
	Hydrogen sulphide.	Orange precipitate.	Add reagent to solution to be tested.
Atropin.	Sulphuric Acid. Potassium dichromate.	Odor of bitter almonds.	Add the reagents to substance to be tested.
Bile:— Acids.	Fresh solution of sugar and dilute sulphuric acid.	Yellowish red color, passing into crimson.	Add a few drops of liquid to be tested to the reagents. (*Pettenkofer's test.*)
Pigments.	Chloroform and nitric acid.	Play of colors, finally ruby-red.	Shake liquid with the chloroform; decant; allow liquid to evaporate; add a drop or two of nitric acid.
Blood.	Tinct. guiaci and oil of turpentine.	Blue color.	Shake the solution of reagents to an emulsion, and add the solution to be tested. Examine drop of solution for corpuscles.
Caffeine.	Solution of red mercuric oxide in potassium iodide.	Crystalline precipitate.	Add reagent to liquid to be tested. Other alkaloids give granular precipitates.
Calcium.	Oxalic acid.	White precipitate.	Add solution of the reagent to solution of substance to be tested.
Cholesterin.	Concentrated sulphuric acid diluted with one fifth its volume of water.	Solution of substance with red color.	On a glass under the microscope add reagent to substance to be tested. The addition of iodine gives violet color. (*Moleschott's test.*)
Carbonates.	Hydrochloric acid and lime water.	White precipitate.	Put solution of carbonates into a flask provided with thistle tube and delivery tube; add acid through the thistle tube to the solution; connect the delivery tube with test tube containing the lime water.

TEST.	REAGENT.	REACTION.	APPLICATION AND REMARKS.
Chloral (hydrate)	Gum camphor. Concentrate solution of dichromate of potassium, nitric acid.	The two solids form a liquid. Blue solution.	Rub together the two solids. Warm the substance to be tested with the dichromate solution, and then add the nitric acid. Odor of chloral is characteristic.
Chloroform.	Hydrogen sulphide. Piece of copper wire.	Intense blue color.	Pass the hydrogen sulphide gas through the chloroform contained in a flask provided with a jet tube; then ignite gas as it comes from the jet tube; hold wire in the flame. The odor of chloroform is characteristic.
Chondorin.	Tannic acid.	Give a precipitate.	Add the acid to a solution of the substance to be tested. Gelatin gives no precipitate with tannic acid.
Caseinogen.	Magnesium sulphate.	Curdy precipitate.	Add the magnesium sulphate to the liquid to be tested until the solution is saturated.
Elastin.	Neutral solution of mercuric nitrate.	Crimson or pink solution or precipitate.	Heat the solution of the substance to be tested with the reagent.
Ether.	Small pieces of glass.	Boils.	Fill test tube half full of ether, add number of small pieces of glass. The liquid of ether should boil on being held inclosed in the hand. Ether is more volatile than chloroform.
Fat (in tissues).	Weak solution of osmic acid.	Black color.	Stain tissue with reagent.
Gelatin.	Water.	Absorbs water, but does not dissolve.	Add water to substance. (*Lea's [Carey] test.*)

TEST.	REAGENT.	REACTION.	APPLICATION AND REMARKS.
Glucose.	Acid solution of mercuric nitrate.	Red solution.	Add the reagent.
	Fehling's solution.	Brown red precipitate.	Add the reagent to a solution of the substance to be tested; boil.
Glycogen.	Solution of iodine in potassium iodide.	Deep red color.	Add the reagent to the solution.
Glycerin.	Carbolic acid, sulphuric acid, and ammonia.	Carmine red color.	Evaporate liquid to dryness, and heat to 120° C; add two drops of the carbolic acid and the sulphuric acid, dissolve in water, and then add the ammonia.
"Hypo" (thiosulphate of soda).	Lead acetate.	Black precipitate.	Add reagent to solution of substance.
	Silver chloride.	Dissolves.	Add the reagent.
Iodine.	Starch paste.	Black or purple color to the paste.	Add the iodine solution to the paste.
Iodates.	Starch paste. Chlorine water.	Black or purple color to the paste.	Add solution of iodates to the starch paste; add a few drops of the chlorine water.
Iron.	Hydrochloric acid, ferrocyanide of potassium.	Blue precipitate or colored solution.	Dissolve the iron in the hydrochloric acid; add the ferrocyanide of potassium.
Kreatinin.	Dilute solution of ferric chloride.	Dark-red color increased by warming.	Add reagent to substance tested. (*Thudichum's test.*)
Lead (salts).	Strong solution of dichromate of potassium.	Orange yellow precipitate.	Add the sol. of the dichromate to a solution of the lead salts.
Magnesium.	Ammonia, hydrogen disodium phosphate.	White precipitate.	Add to the solution of the magnesium salt the ammonia, and then the phosphate solution.
Morphine.	Sulphuric acid solution of sodium sulphide.	Flesh color, violet, dark green.	Dissolve the morphine in the sulphuric acid; add two or three drops of the sodium solution; heat cautiously.
Opium.	Persulphate of iron.	Red color.	Add the reagent to substance to be tested.

TEST.	REAGENT.	REACTION.	APPLICATION AND REMARKS.
Peptone.	Potassium hydroxide and copper sulphate.	Purplish red solution.	Add to solution of peptone a strong solution of potassium hydroxide, then the solution of copper sulphate.
Phosphates.	Hydrochloric acid, ammonium molybdate.	Yellow precipitate.	To a solution of the phosphate add a few drops of the acid, and then a solution of the ammonium salt.
Potassium.	Platinum chloride ($PtCl_4$).	Yellow precipitate.	Add reagent to solution of potassium salt.
Proteids.	Concentrated hydrochloric acid.	Violet red color.	Boil substance with reagent. (*Liebermann's test.*)
Pus.	Alcoholic solution of guaiac. Potassium iodide.	Blue color.	Expose the solution of the guaiac until it turns green on the addition of the solution of potassium iodide. Then add reagent to the solution of pus.
Quinine.	Chlorine water. Powdered potassium ferrocyanide.	Pink to deep red color.	Add the substance to the chlorine water, and then add the ferrocyanide.
Salts:—			Add the sulphuric acid, and test for acid thus formed, as hydrobromic, etc. See tests for acids.
Bromides.	Sulphuric acid.		
Carbonates.	Sulphuric acid.		
Chlorides.	Sulphuric acid.		
Citrates.	Sulphuric acid.		
Iodides.	Sulphuric acid.		
Nitrates.	Sulphuric acid.		
Sodium.	Potassium pyroantimonate.	Gives precipitate.	Add reagent to solution of the sodium salt.
Starch.	Iodine solution.	Blue to blue-black color.	Make a starch paste and add reagent.
Strychnine.	Sulphuric acid and potassium chlorate.	Maroon-red color.	Add the potassium chlorate to the acid. *Add chlorate very carefully, as the action of the acid is quite violent.*
	Chromic acid.	Violet color. (*Brieger's test.*)	Add the reagent to solution tested. (*Slater's test.*)
Tannin.	Ferric chloride solution.	Black ink solution.	Add reagent to substance to be tested.

TEST.	REAGENT.	REACTION.	APPLICATION AND REMARKS.
Theobromine.	Chlorine water. Ammonia.	Purple color.	Add substance to chlorine water, and evaporate to dryness; add the ammonia.
Tin.	Hydrogen sulphide.	Brown sulphide.	Add the solution of the hydrogen sulphide to solution of the substance.
	Potassium hydroxide.	White precipitate.	Add reagent tc the substance.
Urea.	Alcohol and concentrated nitric acid.	Six-sided crystals of urea nitrate.	Evaporate substance to consistency of syrup; add the alcohol, and then distill off the alcohol; add the nitric acid.
Urine:— Albumin.	Nitric acid and ammonia.	Yellow precipitate.	Boil the urine; add the nitric acid, and then add the ammonia.
Pus.	See above.		
Sugar.	Fehling solution.	Red-brown precipitate.	Add the reagent to the urine, and boil.
Uric acid.	Nitric acid and ammonia.	Beautiful red color.	
Water:— Hardness.			Test for calcium and magnesium.
Organic impurities.	Solution of potassium permanganate.	Solution decolorized by organic substance.	Add the water to the reagent, and set away in warm place for twenty-four hours.
Nitrates.			See test for nitrates.

IV. POISONS AND THEIR ANTIDOTES.

SOURCES OF THE COMMON POISONS.

Acetic acid — Vinegar, sugar of lead.
Acid, carbolic — In many disinfecting washes.
Acid, pyrogallic — In most developers used in photography.
Acid, tartaric — In artificial lemonades.
Antifebrin — The free drug and in antikamnia, a common headache powder.
Arnica — In many liniments.
Arsenic — In wall paper, glazed cards, insect powders, many ague medicines, in some paints, many sprays for trees and bushes (Paris green).
Atropin — In the leaves and berries of many of the plants of the Nightshade Family, in many plasters.
Chloral hydrate — In some headache and toothache medicines.
Chloroform — In some cough medicines.
Coal gas (Carbon monoxide) — From burning of charcoal, as in "self-heating" irons, etc.
Copper and its salts — Brass spoons and vessels.
Digitalis — Some cough medicines, many heart and kidney cures.
Ergot — Rye bread.
Fungi (Muscarine) — Mushrooms, toadstools, and truffles. It should be remembered that there are no sure rules for telling the nonpoisonous forms from the poisonous forms, and, unless the specimen is known to be nonpoisonous, it is not safe to experiment.
Iodine and its compounds — In many medicines, especially in combination with sarsaparilla.
Lead and its compounds — From the solder in cans, from lead pipes and paints.
Niter (Potassium nitrate) — Sugar-cured meats.
Opium and opiates — Laudanum, paregoric, soothing syrups, many cough medicines, medicines for relieving pain. *Remember children bear opiates poorly. Begin with the minimum dose, and watch carefully its effect.*
Phosphorus — In matches and some insect powders.

Ptomains — In milk, meat brines, canned meats, putrefied flesh, dissection wounds.
Tin and its salts — From acid fruits in tin cans.
Wintergreen — Flavoring of many medicines and candies.

GENERAL RULES TO BE OBSERVED IN CASES OF POISONING.

1. If the symptoms are serious, get a physician at once.

2. Inquire quickly into the history of the case.

3. Notice odor of the breath, nature and color of the excreta, any stains about the person or clothing.

4. Notice condition of the pulse, the respiration, and the pupils.

5. Notice the temperature; and if low, warm the body by friction and hot application to the extremities.

6. In case of weak heart, give heart stimulant, such as strong coffee, diluted ammonia, or aromatic spirits of ammonia.

7. If the patient can swallow, drinking hot water stimulates the respiration. Vapor of ammonia or ether stimulates the respiration.

8. For vegetable poisons use mustard as an emetic; let patient drink freely of warm water; keep patient awake; give strong coffee as a stimulant. If the patient cannot swallow, the coffee may be given by rectal injection.

9. Acids are corrosive and cardiac and respiratory depressants; hence, give something at once to neutralize the acid, as lime, magnesia, chalk, and mucilaginous drinks to counteract the corrosion of the acid; stimulants to support the respiration and the heart.

10. Alkalies [1] are irritants and depressants; give, therefore, demulcent drinks, as milk, oils, and organic acid, as vinegar or lemon juice, to counteract alkali. Do not use emetics in case of alkalies.

11. In case of threatened failure of the respiration use artificial respiration.

12. Do not get excited. Keep up the courage of the patient.

---

[1] Ptomains are sometimes called putrefactive alkaloids on account of their basic nature and the alkaline medium in which they are formed. In their general action they are irritants, causing nausea, vomiting, and severe pain. In their more specific action, they may be grouped into those acting like (1) morphine, (2) digitalis, (3) nicotine, (4) Strychnine, (5) Atropin, (6) Veratrine. Give gastric and intestinal antiseptics, as salol or bismuth naphtolate, in addition to other remedies.

TABLE OF POISONS.

(Compiled from "Gould's Illustrated Dictionary of Medicine.)

NAME.	SYMPTOMS OF POISONING.	TREATMENT AND ANTIDOTES.
Acetanalid.	A bluish discoloration of the skin, extreme weakness and depression.	Keep body warm; heart stimulants; strychnine; artificial respiration if necessary.
Acid:—	Corrosive.	Alkalies; soaps.
Acetic.	Vomiting; purging; sourness of the breath; pain in stomach.	Alkalies; soaps; mucilaginous drinks; opiates (but given with great caution).
Arsenous.	See arsenic.	
Arsenic.	See arsenic.	
Carbolic.	Burning pain from mouth to stomach; mucous membrane of mouth and throat white; dizziness; unconsciousness; low temperature; pupil contracted; characteristic odor.	Emetics; magnesium sulphate; opiates to relieve the pain; alcohol or atropin; a syrup of lime. Warm application to feet.
Chromic.	Yellow stains on mouth and mucous membrane, abdominal pains and vomiting; extreme depression.	Emetics; chalk, lime water, milk, or albumin; mucilaginous drinks.
Hydrochloric.	Pain throughout digestive tract; vomiting; feeble pulse; clammy skin; great depression; blistering of the flesh; yellow stains on clothing, but not on skin.	Alkalies; demulcent drink; oil; stimulants.
Hydrocyanic.	Labored breathing; vomiting; purging; spasm; rigidity; irregular heart; characteristic odor.	Dilute ammonia; heart stimulant (atropin); opiates, to relieve the pain; alternate application of cold and hot water to the body; artificial respiration.
Lactic (concentrated).	Severe irritations of the alimentary canal.	Alkali and demulcent drinks.
Nitric.	Yellow stains on the skin; other symptoms like sulphuric acid.	Alkalies, demulcent drinks, and stimulants.
Oxalic.	Hot, acrid taste; burning; vomiting; extreme depression.	Lime water, chalk, and demulcent drinks.
Pyrogallic.	Vomiting, diarrhea, fever, rigor, black urine, very labored breathing.	Mineral acids; alkalies; salts of iron. Watch the respiration and the heart. Give stimulant if necessary.
Salicylic.	Dilated pupil; quick and deep respiration; more or less delirium: low arterial pressure: roaring in the ears, with deafness; rapid pulse.	Stimulants; alcoholic drink.
Sulphuric.	Black stains (see hydrochloric acid); profuse and bloody salivation.	Chalk or limewater; magnesia; soap; demulcent drinks.
Tartaric.	Pain in abdomen; vomiting; depression.	Magnesia; lime; soap.
Alcohol.	Confusion of thought; dizziness; staggering; flush of face; livid lips; convulsions; depression; coma; breath the odor of alcohol.	Emetic; strong coffee; hot and cold douches of water; amyl nitrite.

NAME.	SYMPTOMS OF POISONING.	TREATMENT AND ANTIDOTES.
Ammonium and its compounds.	Burning pain in mouth, chest, and stomach; swollen lips and tongue; labored breathing; vomiting of blood; characteristic odor.	Vegetable acids; demulcent drinks.
Aniline.	Dizziness, apparent intoxication, sweating, blue color of mucous membrane of mouth; odor of aniline.	Emetic; stimulant for both heart and respiration; artificial respiration; administration of oxygen.
Antifebrin (see Acetanilid).		
Antimony and its salts.	Metallic taste, difficulty in swallowing, violent vomiting, pain and burning in the stomach, purging; cramps; great depression.	Tannic acid; milk or oils; opium; alcohol; ether.
Antipyrin.	Headache; blue color of the skin; dizziness; drowsiness; confusion of ideas; great depression and prostration.	Recumbent position; strychnine; stimulants; artificial respiration.
Arnica.	Transient excitement; unconsciousness; dilated pupils; extreme depression, paralysis.	Give cardiac stimulants.
Arsenic and its compounds.	Violent burning pain in stomach, straining in vomiting, thirst, diarrhea, burning in the urinary passages, with suppression of the urine; sense of constriction and dryness of the throat; feeble and rapid pulse; in chronic poisoning, part around the eyes swollen.	Freshly precipitated iron hydroxide with magnesia, emetics, demulcents. To make the hydroxide, to ferric sulphate solution (10 parts) add ammonia (11 parts); filter, and wash precipitate. Magnesia, 1 part to 75 parts of water. Add the magnesia solution to a solution of hydroxide (iron 25 to 50 parts of water). Give in large and frequent doses. Keep the two solutions in separate bottles, ready for use when needed.
Atropia (Nightshade, Belladonna). Atropin.	Heat and dryness of the mouth and throat, suppression of the saliva, difficulty in swallowing, great thirst, indistinct vision, great dilation of the pupils, delirium, skin dry and flushed, very rapid pulse.	Give emetics; give strong coffee; keep extremities warm; artificial respiration.
Caffeine.	Burning pain in the throat, dizziness, faintness, abdominal pain, great thirst, dry tongue, tremor of extremities, weak pulse, cold skin, increased flow of urine.	Emetics, morphine and stimulants, warmth.
Calcium (see Lime).		
Camphor.	Characteristic odor, weakness, dizziness, indistinct vision, delirium, convulsions, clammy skin, smarting of urinary organs, feeble but rapid pulse. There is no pain, vomiting, or purging.	Emetics, stimulants, warmth, hot and cold douches.
Cannabis indica (Indian hemp).	Pleasurable intoxication, dilated pupils, sense of prolongation of time, tremor of the limbs, weakness.	Strychnine, stimulants, evacuation.

NAME.	SYMPTOMS OF POISONING.	TREATMENT AND ANTIDOTES.
Cantharis (Spanish fly).	Tenderness of the abdomen, mucous or bloody stools, vomit mucus and containing shiny particles, blood and albumin in urine, convulsions, coma, unconsciousness.	Emetics, demulcent drinks, morphine.
Carbolic acid (see Acid).		
Carbon Disulphide (Bisulphide).	Headache, dizziness, excitement, rigor of the muscles, characteristic odor in breath and discharges.	Emetics, warmth, stimulation, artificial respiration.
Chloral hydrate.	Deep sleep, loss of muscular power, slow respiration and weak pulse, pupils contracted during sleep, but dilated when awake.	Emetics; keep up temperature by hot bottles, hot blankets to feet, and friction; keep patient awake; hot coffee, heart stimulant, strychnine; artificial respiration if necessary.
Chlorine.	Characteristic odor, irritation of the throat and air passages, sense of tightness across the chest; swallowing difficult.	Fresh air; inhalation of dilute ammonia, ether, or chloroform.
Chloroform.	At first slight stimulation, excitement (in reality, depression), incoherent speech, relaxation of muscles, and insensibility.	Draw the tongue forward; fresh air; heart and respiratory stimulants; rectal injection of normal saline solutions and hot coffee; artificial respiration; breathing of amyl nitrite or ammonia.
Citric acid (see Acid).		
Coal gas.	Odor of gas, headache, dizziness, suffocation, loss of muscular power, unconsciousness, dilated pupils, labored respiration.	Fresh air, ammonia, artificial respiration, stimulants, hot coffee, hot and cold douches.
Cocain.	Feeling of faintness, dizziness, weak, nausea, rapid and intermittent pulse, extreme prostration, slow and feeble respiration.	Heart and respiratory stimulants, amyl nitrite.
Copper and its salts.	Metallic taste in the mouth, thirst, black decoloration of mucous membrane, griping and colicky pain, nausea and vomiting, purging with straining, hurried respiration, weak but rapid pulse, weakness.	Emetics, morphine; poultices to stomach; barley water; demulcent drinks.
Creosote (see Carbolic Acid).		
Cronton tiglium (Croton oil).	Intense abdominal pains; vomiting, purging, pinched face; weak, thready pulse; moist skin; great prostration.	Emetics, demulcent drinks, camphor, stimulant, morphine, poultices to abdomen.
Cyanogen and its compounds.	Same as those of hydrocyanic acid, which see.	
Datura stramonium (Jamestown Weed).	Like those of atropin, which see.	

NAME.	SYMPTOMS OF POISONING.	TREATMENT AND ANTIDOTES.
Digitalis pupura (Fox-glove).	Purging, with severe pains; vomiting, the matter being of grass-green color; weak, irregular, and slow pulse; headache, delirium and convulsions; pupils dilated; skin cold.	Emetics, tannic acid, stimulants, aconite, recumbent position.
Dog bite (see Saliva).		
Ergot.	Tingling of the fingers and feet, cramps in the extremities, dizziness, weakness, dilated pupils, weak pulse, vomiting and retching.	Emetics; quick purgatives, Epsom salts, tannic acid, stimulants, recumbent position.
Ether.	Sense of choking, cough, excitement, relaxed muscles, insensibility.	Treat as in chloroform poisoning, which see.
Fungi (mushrooms, toadstools, truffles, many species of which are poisonous).	Catarrh of the stomach and intestines, nausea, vomiting and purging, heat and pain, fainting, convulsions, weak and frequent pulse, pupils dilated, delirium, stupor.	Emetics, quick purgatives, Epsom salts, stimulants, atropin.
Insects, Poisonous (the bite or sting).	In most cases the symptoms are slight, but in case of tarantula, scorpion, and centipede, may be very serious; pain, swelling, fever, suppuration, possible gangrene, and death.	In mild cases, ammonia or baking soda applied to wound; soap, repeated washing. In very severe cases, treat same as for bite of snake, which see.
Iodine and its compounds.	Pain in throat and stomach; vomiting, the material being yellow, or, if starch is present, blue or nearly black; dizziness, faintness, convulsions, singing in the ears, rapid pulse, ravenous appetite.	Emetics, starch; morphine; chew pellitory to eliminate the iodine.
Iodoform.	Slight delirium, drowsiness; emaciation; fever; rapid pulse; symptoms like those of meningitis.	Wash the wound with oil of eucalyptus.
Ipecacuanha (Ipecac).	Vomiting; vomit containing food; depression.	Evacuate.
Iron and its salts.	Metallic taste, pain, vomiting, purging, vomited matter black.	Magnesia, drink freely of water; ice, opium.
Lactic acid (see Acid).		
Laudanum (see Opium).		
Lead and its compounds.	Dryness of the throat; great thirst; metallic taste; colic relieved by pressure; rigidity of abdominal muscles; constipation, cramps in lower limbs, convulsions; in chronic forms blue line on margin of gums.	Emetics, dilute sulphuric acid, Epsom salts, milk, morphine, iodide of potassium to eliminate the lead, poultices to the abdomen.
Lime.	Burning pain in abdomen; great thirst; obstinate constipation.	Vegetable acids, demulcent drinks.
Lobelia (Indian Tobacco).	Severe vomiting; great depression; dizziness; tremors; convulsions.	Evacuate, tannic acid, stimulant, strychnine, warmth, recumbent position.

NAME.	SYMPTOMS OF POISONING.	TREATMENT AND ANTIDOTES.
Meat (from ptomains from putrefaction).	Severe irritation of stomach and intestines, nervousness, prostration.	Emetics, purgatives, sedatives, stimulants in case of prostration or weakness.
Mercury and its compounds.	Acrid metallic taste; burning sensation in throat and stomach: vomiting; diarrhea, with bloody stools; lips and tongue white and shriveled; pulse weak and frequent; coma. Secondary symptoms: Hectic fever, coppery taste, fetid breath, gums swollen, salivation.	Albumin in some form, raw white of egg or flour, evacuate, potassium iodide, opium.
Milk (tyrotoxicon).	Nausea, diarrhea, cramps, prostration.	Emetics, intestinal antiseptics, stimulants.
Morphine (see Opium).		
Mushrooms (see Fungi).		
Niters (see Potassium nitrate).		
Nitric acid (see Acid).		
Nux vomica (see Strychnine).		
Opium. Morphine. Laudanum.	At first, excitement, quickened pulse; later, headache, weariness, sensation of weight in limbs, stupor, diminished sensibility, contracted pupils; person difficult to arouse; reflexes abolished; jaw falls, respiration slow, irregular, and stertorous; pulse weak.	Evacuation; keep person awake; ammonia, strong coffee, atropin, strychnine, artificial respiration, potassium permanganate.
Oxalic acid (see Acid).		
Paris Green (see Arsenic).		
Peach-kernel (see Hydrocyanic acid).		
Petroleum.	Burning in alimentary tract, excreta covered with layer of oil, skin cold, feeble but regular pulse, respiration, sighing, thirst, restlessness.	Emetics, stimulants, warmth, stimulation of skin, artificial respiration.
Phosphorus.	Vomiting and pain; garlicky odor to breath; vomit may be luminous in the dark, and has odor of phosphorus; heart weak; tendency to hemorrhage; coma or delirium; albumin in urine.	Sulphate of zinc or copper, Epsom salts. *Never give oils or fats.*
Poison vine (see Rhus).		
Poison oak (see Rhus).		
Pokeberries (Phytolacca).	Nausea, vomiting, depression, pulse and respiration weak, tetanic convulsions.	Evacuate, alcohol, opium, ether, digitalis.
Potassium and its compounds.	The hydrates and carbonates act like lime, which see; the salts like acid, from which they are derived.	Vegetable acids, demulcent drinks, oils.
Prussic acid (see Hydrocyanic acid).		

NAME.	SYMPTOMS OF POISONING.	TREATMENT AND ANTIDOTES.
Pyrogallic acid (see Acid).		
Rhus (Poison vine, Poison Oak).	Irritation of the skin; itching, swelling, and vesicular eruption; inflammation may spread to the throat, producing cough; thirst, vomiting, colicky pains, fever, delirium.	Rub with *Grindelia;* carron oil and solution of acetate of lead; rest, laxatives, opium.
Salicylic acid (see Acid).		
Saliva of Rabid Animals.	It is rare that the symptoms are shown before three weeks; may occur between that and many years; pain in bitten part; uneasiness, languor, difficult respiration, difficulty of swallowing, horror of water, violent convulsions, tongue swollen, flow of viscid saliva.	*Preventative:* immediate ligature above wound; excision, cautery. *Of hydrophobia:* chloroform internally, morphine, hypodermatically, cocain to throat, nutritive injections.
Silver and its salts.	Pain, vomiting, purging, vomit white and cheesy, turning black in the sunlight; cardiac depression.	Salt and water; evacuate; albumin; stimulants.
Snake bite.	Vary in different cases, but in most cases pain in bitten parts and rapidly spreading; great swelling of wounded part, which becomes livid, and later gangrenous; fainting, vomiting, and convulsions; pulse feeble, rapid, irregular; labored respiration.	Removal of poison by sucking or cupping; ligature above wound; cut out wounded part, or cauterize; ammonia to wound and internally; warmth; alcoholic stimulants in some cases.
Soda (Sodium) and its salts.	Symptoms and treatment like that of potassium, which see.	
Strychnine.	Tetanic convulsions coming on in paroxysms at varying intervals of from five minutes to half an hour. Muscles in tetanic contraction during paroxysm; eyeballs prominent, pupils dilated, difficult respiration, pulse feeble and rapid, anxiety.	Evacuate; animal charcoal or tannic acid, followed by emetics; keep patient quiet; bromides and chloral, chloroform, artificial respiration in some cases.
Sulphuric acid (see Acid).		
Sumach (see Rhus).		
Tansy.	Odor of tansy in breath, convulsions, insensibility, dilated pupils, rapid respiration, pulse full, gradually falling.	Heart stimulants, evacuate.
Tartar Emetic (see Antimony).		
Tin.	Metallic taste, vomiting and diarrhea, severe pain, depressed heart.	Evacuate; magnesia, mucilaginous drinks, heart stimulant.
Tobacco (Nicotine).	Nausea, vomiting, great weakness, feeble pulse, cold and clammy skin, pupils contracted and then dilated.	Emetics, tannic acid, strychnine, stimulants, warmth, recumbent position.

NAME.	SYMPTOMS OF POISONING.	TREATMENT AND ANTIDOTES.
Turpentine.	Odor of turpentine; intoxication; contracted pupils; stertorous breathing; coma; tetanic convulsions; urine has the odor of violets.	Evacuate, magnesium sulphate: demulcent drinks; morphine.
Veratrum (Hellebore).	Burning pain in alimentary tract; cannot swallow; vomiting and diarrhea; palpitation at first, then slow, weak pulse; labored respiration; pupils generally dilated, convulsions in some cases.	Evacuate; ether hypodermatically; opium; stimulants; coffee; warmth; recumbent position.
Wild Cherry (see Hydrocyanic acid).		
Wintergreen (Gaultheria).	Like those of Salicylic acid, which see.	
Woorara (Curare).	Complete paralysis of the voluntary muscles; slowing of the heart beat and respiration.	Artificial respiration; stimulants; ligature, and wash the wound; evacuate the bladder frequently.
Zinc.	Corrosion of the lips or mouth; pain and burning; incessant vomiting, the vomit blood-stained; acceleration of pulse and respiration; labored breathing; dilation of pupils; convulsions, like those of epilepsy; paralysis, coma.	Sodium or potassium carbonate, milk, eggs, tannic acid, morphine hypodermatically; poultices to abdomen.

V. CONTAGIOUS DISEASES.

Micro-Organism. —"From dust thou art, and to dust thou shalt return," is as true in the light of science as in the light of inspiration. It is as true of all organic beings as of man; this is alike the story of the life history of the simple lichen and the giant Sequoia, the king of the forest. The cycle for the plant is mineral, plant, mineral; for the animal it is but a little more continued story of mineral, plant, animal, mineral.

Forms are brought into existence, grow, attain a certain degree of size and power, decline, die, decay, and return to the elements from which they came. Mountains are brought into existence, attain their greatest degree of magnitude and grandeur, decline, crumble by the erosive forces of nature, and are carried into the sea, and are not. Rivers, plains, valleys, lakes, land, and ocean have a similar history, and, may we not say, the earth and all material forms? Change, unceasing change, is nature's law; organization, disorganization. Yet in this ceaseless round the sum total of matter remains the same. Hydrogen is always hydrogen, carbon is carbon, and sodium is sodium, indestructible; but like the ever-changing forms of the kaleidoscope, they are ever making new combinations. To-day, gases in the air, salts of the earth, and constituents of water; to-morrow, protoplasm and cellulose of plant tissue, and then transformed into brain and muscle, bone and nerve, of some animal form; now changed by the organism to carbon dioxide, water, salt, and urea, and next returned to the sources from which they came. Like the fabled Phœnix, the ashes of one form become the germinal grains of other forms. In one sense, we die that others may live. If it were not for this endless chain of changes, the elements of matter would become used up in existing forms, and there would be no material for the formation of new forms, or for the repair of the old.

Many of these changes take place very slowly, others very rapidly. It has taken ages to produce a gorge of a Niagara, but annually millions of plants and animals die, and return to dust. It will take æons to level the mountains to the sea, but in a few hundred years all living forms (except the immortal part of our being — the soul) of earth, air, and

sea will have disappeared, and will have returned to the elements from which they came. The forces by which these changes are produced are also indestructible, and, like matter, are ever changing their forms from molar to molecular, molecular to ethereal, physical to chemical; now potential in its chemico-vital to physical or chemical, chemico-vital, and form, then kinetic; kinetic, then potential. In all this varied transformation, the sum total of energy remains the same.

Some of these forces are constructive; i. e., they so combine the elements of matter as to make it more complex, both as to its structure and properties; others act upon these complex substances, and reduce them to simpler forms. We have seen both of these forces at work in our study of the human body, and similar changes are taking place in every organism, in the plant and animal alike, and even organic products and mineral compounds are not exempt from the action of these forces. When the organism dies, the destructive agents soon decompose it; the giant pine, which was centuries in forming its massive trunk and lofty branches, when uprooted by the storm, decays in a few months or years. The most active agencies in effecting this decomposition, and the return of the organic substances to their mineral constituents, nitrogen, hydrogen, oxygen, carbon dioxide, mineral salts, and ammonia, are *micro-organisms.*

Fermentation and Ferments.—The process by which these micro-organisms effect this decomposition is called *fermentation,* and the agencies by which it is effected are called *ferments.* The term is here used in its broad sense, and to mean all those chemical changes in which a substance, mineral or organic, undergoes change through the agency of an organic substance, derived either from the activity of plants or animals; the substance remaining the same in amount (quantitatively) before and after the reaction.

All ferments have the following properties in common: (1) They are organic nitrogenous substances of either vegetable or animal origin; (2) they are unstable compounds, whose active principle is destroyed by a temperature above 100° C., and by certain powerful reagents (such as *antiseptics*); (3) a small amount of the ferment is capable of producing fermentation in a relatively large amount of the substance to be fermented.

As to their origin, ferments are of two classes: (1) Those

1. Consumption. Bacilli.

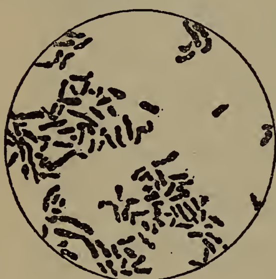
a, "Zeiss $\frac{1}{18}$" Oil-immersion, Ocular 4, tube drawn out. (Koch.) *b*. Bacillus tuberculosis in sputum. x 1,000. (Baumgarten.)

2. Pneumonia. Bacillus of Friedlander.

a, From a culture. *b*, from blood of mouse showing capsule. (Flugge.)

3. Pneumonia. Micrococcus.

From blood of rabbit inoculated with human saliva x 1,000. (Sternberg.)

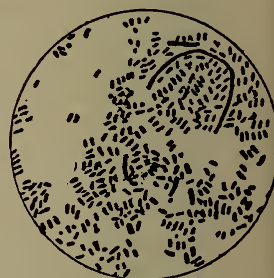


4. Diphtheria. Bacillus.

From a culture of blood serum. x 1,000. (Fränkel and Pfeiffer.)

5. Influenza. Bacillus.

From bronchial mucus. x 1,000. (Fränkel.)



6. Typhoid Fever. Bacillus.

From single gelatin colony. x 1,000. (Sternberg.)

7. Erysipelas. Streptococci.

From pus. x 800. (Flugge.)

8. Anthrax. Bacillus.

From a culture showing formation of spores. x 1,000 (Klein.)

9. Cholera. Asiatic.

Spirillum. x 1,000. (Koch.)

Fig. 176.—ILLUSTRATIONS OF VARIOUS DISEASE GERMS. (Michigan State Board of Health.)

which have a definite structure, and are capable of multiplication and growth, and hence called *organic ferments* (*zymazes*); e. g., the yeast plant (*saccharomyces cerevisivæ*); (2) those, while produced by plants or animals, are unorganized, incapable of reproduction, but may pass into a solution, and be recovered from the solution when desired in the same way as ordinary chemical compounds, and hence are called *unformed* or *soluble ferments* (*enzymes*); e. g., pepsin of the gastric juice..

The more important classes of organic ferments are: (1) Those like our common molds, *fungi;* (2) those like the yeast plant, *saccharomyces;* and (3) those very small in size, of a great variety of forms, and reproducing by fission, *bacteria.* The first group is not very important in the production of fermentation; the second is much more important, being the agents which produce *vinous fermentation;* the third group is far more numerous in the number of species in the group, produces a much greater variety of fermentation, and hence is more important. The first group is little affected by acid media, but the second is more sensitive in this respect than the first, while the third group, with a few exceptions, as the acetic acid ferments, is very sensitive to an acid media, and hence the value of acids as antiseptics.

The bacteria, as to the product they make, are classed into three groups: those producing pigments (*chromogenic*); those that produce fermentation (*zymogenic*); and those that produce disease (Fig. 176), both in plants and animals (*pathogenic*). As has been stated, they have a great variety of forms, but for convenience of study they may be classed into three groups: those made up of more or less spherical-shaped bodies, either isolated or grouped, *micrococci;* those that are rod shaped, *bacilli;* those looking like spiral short threads, *spirilli.* Of the ferments, the bacteria are the more widely distributed, being found in the air, the water, the earth, or plants, in the various organs of animals, in cold as well as hot climes, though in the latter condition they are much more numerous. The bacteria are far more numerous as to the number of species and in the number in each species.

The mode of action of ferments is too complex to be given in an elementary treatise, yet it is of importance for us to know the more general nature of these actions. They

may be stated briefly as, (1) those which produce fermentation by hydration, as the change of starch to sugar; (2) those producing fermentation by decomposition, as the changing of dextrose to lactic acid; (3) by reduction, as in butyric fermentation; (4) by oxidation, as the conversion of sugar into alcohol (*ethyl alcohol*). To the latter class belongs the class of fermentation commonly called *decay*. When the decomposition is that of a nitrogenous substance, and results in the production of offensive gases, the process is called *putrefaction*. The decomposition and distintegration of albuminous material often results in the production of active, inanimate, septic, or toxic substances, called *ptomains*. Many of these ptomains are poisonous; the most of them, however, are not. They are found in ice cream, putrefied flesh, putrefied fish, fish-brine, and other sources of putrefaction. Great care should be used in handling putrid materials, hides of animals, and dead bodies, as there is great danger from poisoning through the broken skin, by sores, or wounds. Canned meats and fish should never be left in the cans after opening. Milk cans, crocks, and ice cream freezers should be thoroughly washed with *boiling water before using.*

The action of these micro-organisms is not restricted to dead material or mineral substances, but many of them attack living organisms, and they are the cause of various diseases, as smallpox, consumption, and like diseases, called infectious diseases. It is a well-established fact that most of our diseases are due to some form of specific germ or micro-organism, and in our studies of these we have gained some of our greatest victories; many diseases which a few years ago baffled the best medical skill, and destroyed annually thousands of lives, are now treated with but a very small per cent of loss of life, and less suffering to the patient.

Many of these germs produce, by their action in the system, substances which check the further action of the infectious germ, and in many cases, if the system is strong enough to withstand the effects of the disease, this substance will entirely destroy the disease germ, and the person will recover. This substance is called *antitoxin*. If this antitoxin is taken from a diseased animal and given to a person just taking the disease, the severity and duration of the disease may be very much lessened, or entirely overcome.

Some of these diseases so affect the system of the person having them that they render him incapable of having them again, or the person may be inoculated with a mild form of the disease, and the system become protected against the more malignant form; this condition of the system is called *immunity*.

While most of these diseases are treated with great skill, and death has been reduced to a minimum, yet our greatest protection comes from their prevention. The more important ways by which this has been effected are: (1) The isolation of the person diseased so that he will not come in contact with others, and infect them, and thus spread the disease; (2) by *disinfecting*; i. e., treating the clothing or articles used by the person, and the premises, with substances which kill the disease germs, and prevent *contagion;* (3) by removing the conditions favorable to the growth of the germs, as draining the stagnant pond, cleaning the filth from the street, and contamination of our drinking water with sewage; and (4) by keeping our houses as free from dust as possible, and letting in an abundance of sunlight and air.

Disinfecting.—This is one of the most important means of preventing the spread of disease. For articles that can be boiled, boiling for twenty or thirty minutes in water is a very effective method of disinfecting, as there are few germs, if any, that are not killed by heating in water at 100° C., but clothes containing the expectorations of persons having diphtheria, scarlet fever, and consumption should be burned.

The more important substances used in disinfecting are sulphur, carbolic acid, corrosive sublimate, chlorinated lime, and formalin.

All vessels that can be cleaned by boiling hot water should be washed with corrosive sublimate (1 part of corrosive sublimate to 1,000 parts water), carbolic acid, or strong chlorine water (ten per cent of chlorine). The fecal discharges of persons having typhoid fever and like diseases should be disinfected by mixing them thoroughly with one ounce of chlorinated lime and a teaspoonful of carbolic acid before throwing them out.

The clothing and bedclothing of persons having smallpox or scarlet fever may be disinfected by putting them in a closed closet and fumigating them with chlorine set free from chlorinated lime treated with carbolic acid (two ounces of

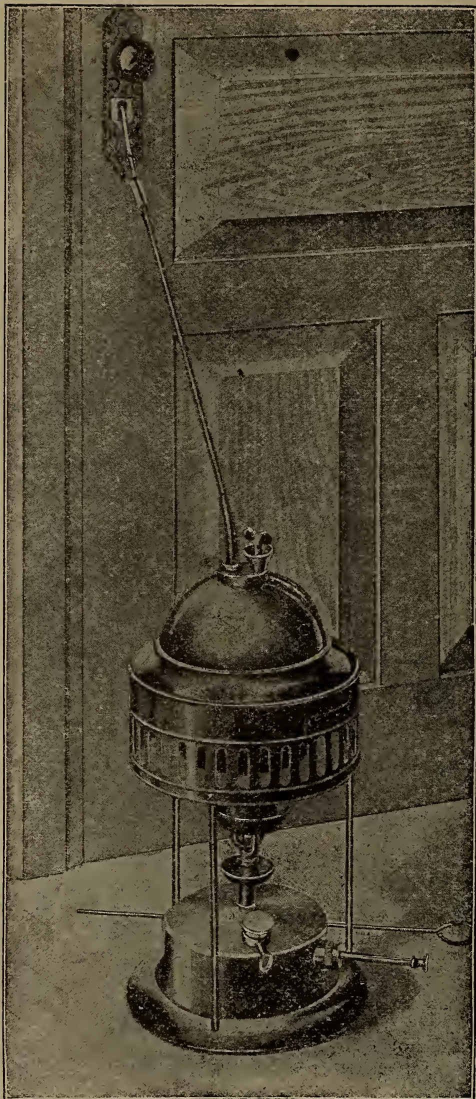


FIG. 177.—THE NOVY APPARATUS FOR FORMALDEHYDE DISINFECTION.
(Parke, Davis & Co., Detroit.)

lime to a tablespoonful of carbolic acid), leaving them for several hours. Strong acids should not be used, as they will set the chlorine free in such large amounts as to bleach and injure the clothes. The sick-room may be disinfected in a similar way, but by using larger amounts of the materials. There is no need of destroying the clothing, the beds, or furniture, as proper disinfecting will prevent any possible contagion. Formalin is a very effective disinfecting agent. A room may be fumigated (Fig. 177) by passing the vapor from a formalin still into the room by means of a tube running from the still through the keyhole of the door. Eight ounces of a forty-per-cent solution, under favorable circumstances, will disinfect one thousand cubic feet of space, and for larger space proportionate amounts. If the vapor can escape through the cracks of the doors or window, due allowance must be made, and the amount proportionately increased. The vapor of formalin does not injure the most delicate fabrics: it rusts iron, but does not injure other metals.

DISEASE: ITS MORE COMMON CAUSES AND PREVENTION.

Causes of Disease. — Disease is a disorder of the structure or function of the body. Its causes are numerous. The more important are: (1) mechanical, as an injury from a wound, a sprain, or a fall; (2) the result of exposure to cold or wet, in which the body becomes chilled, producing congestion of the internal organs, or what we call *"a cold;"* a cold should be watched with the greatest care, and means should be taken at once to cure it, as it lowers the tone of the system and makes possible the attacks of disease germs, which under a healthy condition may be thrown off, but in case of a deep cold find foothold, and develop into pneumonia, consumption, or fevers; (3) improper eating, either as to quantity, quality, or the time and manner of taking the food; (4) irregular habits, insufficient sleep, overwork, or a lack of exercise; (5) dissipation of any kind; (6) the contact with specific disease germs of contagious disease, as the bacilli of consumption, diphtheria, or typhoid fever.

Many of these germs are in the air, the water, the soil, or in our food, and any lowering of the tone of the body renders it unable to throw them off. Other forms are not common, and are spread only by the person coming in con-

tact with the diseased persons, as in smallpox, scarlet fever, and measles. These germs attack the most robust.

Prevention of Disease.—The more important precautions toward the prevention of disease are: (1) regularity of habits of eating, sleep, work, and recreation; (2) keep the feet and body dry, and the skin and excretory organs active; (3) breathe pure air, by avoiding infected air and poorly ventilated rooms, and take plenty of simple, wholesome food; (4) *avoid all narcotics and stimulants;* (5) by scrupulous cleanliness, prevent the collection of dust or filth that may become the hotbed of disease germs; (6) the isolation of persons affected with contagious diseases, and thorough disinfection of rooms and articles used by persons thus affected; (7) by immunity, as in case of smallpox, by vaccination, or by the administration of antitoxin in case of diphtheria; (8) by calling the attention of the health officers to any suspicious sore throat or eruptive disease, and at once isolating the person; (9) in case of wounds and sores, to keep them protected from the air, and to antisepticize the bandages and wounds.

DANGEROUS COMMUNICABLE DISEASES.

The following facts have been taken from the bulletins of the Michigan State Board of Health: —

Consumption. — Consumption is a dangerous and communicable disease. As shown in Fig. 178, it is the most fatal of communicable diseases, many times more so than the so much dreaded smallpox, and in fact more than any other disease. Though the lungs are generally the seat of the disease, other parts of the body may be attacked, as the alimentary tract, the joints, and the lymphatic glands. It is spread by the dust of the dried sputum, in milk, and in the meat of tuberculous animals. While there is the hereditary transmission, it is now established that it is a communicable disease, and any one may become infected by it. A consumptive is a menace to public health, and if the proper precautions are not used, he may spread this dreadful disease. The sputa should never be swallowed, as it will carry the contagion to the alimentary canal, and bring serious complications, and even general tuberculosis.

Any person who has a habitual cough, and who coughs up sputa, should have the sputa examined for bacillus tuber-

culosis. Such a course is better for the person, since he may know his true condition; and if bacilli are present, the disease may be treated in its first stages, as there is hope of recovery if taken at this stage. It is also much better for the public health, as proper precautions can be taken for the prevention of the spread of the disease to the members of the family or other persons that come in contact with the infected person. Delay is dangerous. Every day lessens the possibility of recovery, and the person becomes a greater menace to the public health.

Consumptives should never expectorate where the sputum may become dried, and get in the dust of the air, and

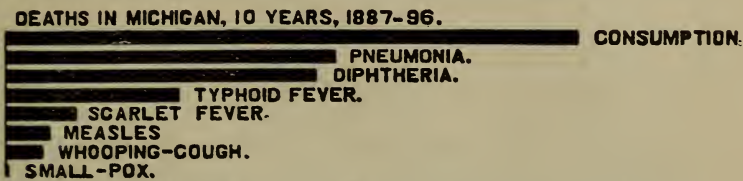


FIG. 178.—RELATIVE NUMBER OF DEATHS FROM VARIOUS DISEASES.

thus become the source of contagion. They should expectorate on small pieces of cloth, and these should be burned at the first opportunity, and never on a handkerchief, in which the sputum may become dry, and be the means of infection to those handling it.

All dejecta of a consumptive person should be destroyed or disinfected. A good disinfectant is chlorinated lime with carbolic acid, one ounce of the lime and one teaspoonful of acid to each discharge, or in its stead one quart of "Standard Solution No. 1." Cuspidors used by consumptives should be disinfected with wood vinegar. Consumptives should not use the same towel or drink from the same vessel used by others.

Pneumonia.—This ranks next to consumption in the fatality it produces. This is a disease of the lungs, and it is produced by micro-organisms which gain access to the lungs, and which multiply rapidly. The disease has a rapid course, and may end fatally in five or ten days. Any one of three organisms may produce this disease. It is spread, like consumption, by the germs contained in the sputa. This is a very dangerous disease, and most prevalent in the colder months. All sputa should be disinfected, and great care

taken to prevent colds. Pneumonia sometimes becomes epidemic.

Meningitis.— Like pneumonia, this seems to be due to more than one germ. It is a disease of the coverings of the brain and spinal cord. It frequently accompanies outbreaks of pneumonia, and the same germs may be present in either of these diseases; in one case acting on the lung tissue, producing pneumonia, and in the other on the membranes of the brain or spinal cord, producing meningitis. The best protection is to avoid exposure.

Influenza.—This disease is commonly known as the "grippe." It has been quite prevalent for the past ten years. It is caused by a specific germ. These germs are found in the bronchial and nasal secretions and in the saliva of the person affected with the disease. It is sometimes fatal. It is often epidemic. Very frequently it is followed by pneumonia or meningitis. When epidemic, it seems that the meteorological conditions are the primary causes for the lack of power to resist the germs of influenza, as well as those of pneumonia, meningitis, and consumption. During such epidemics great care should be taken of the health. The towels, cups, etc., used by the sick person should not be used by others until thoroughly washed in *boiling* water.

Diphtheria.—This disease is due to a specific germ peculiar to this disease. In its activity it produces a powerful poison, and it is to this poison, rather than to the injury to the tissues of the throat, that the sickness and death from diphtheria is due. The bacilli may remain in the mouth for weeks after apparent recovery from the disease, and during this period they may retain their virulence, and sputa containing them is dangerous; hence the importance of keeping the persons who are recovering from an attack of diphtheria under the same restrictions in regard to associating with others, and in disinfecting all vessels or articles used by them, for several weeks after apparent recovery. The fact that the "false membrane" has disappeared is no evidence that danger from contagion is over.

In this, as in other infectious diseases, the use in common by pupils of pencils, chewing gum, drinking cups, or any other articles likely to be placed in the mouth, should be discouraged, and the danger of such practices explained.

Typhoid Fever.—This disease is not often contracted directly from one sick with the disease, but usually from the use of food or water contaminated with the germs from carelessness in not disinfecting the articles and vessels used by the sick person. The chief source of danger, however, seems to be from the drinking water (Fig. 179) which has become infected from sewage or from leakage from water closets.

Freezing does not always kill the germ of typhoid fever, but boiling does. All suspected water should be boiled before using. Milk may become infected with the bacillus of typhoid fever; it is, therefore, best to sterilize it or boil it before using.

It is claimed on good authority that in the late Spanish war that the house flies were the carriers of infections from the contaminated latrines of the soldiers to their food. Flies often become the means of infection, and should be kept from the sick-room.

Scarlet Fever.—There is little doubt that this disease is due to a specific germ, and its infection may be carried from person to person. It is chiefly spread by the discharges from the nose, mouth, and throat, and probably also by the minute scales which are thrown off from the surface of the body. This disease is much to be dreaded, not only on account of the disease itself, but also from the diseases which follow as complications. Do not be deceived by the term "scarlatina;" it is scarlet fever, and treat it as such. Isolation and disinfection are imperative in this disease. Any case of rash or breaking out should be looked upon with suspicion, and the isolation of the person, until its nature is determined by a physician. Such cautions are necessary to the prevention of epidemics. In scarlet fever, and even in diphtheria, a close watch should be made of the urine of the sick person so as to catch the first symptoms of albuminuria, which may follow as complication in this disease. (For tests of the urine see Table of Tests.)

Measles.—This is an infectious disease, and may be spread from person to person either directly or indirectly. The patient should be carefully watched to prevent taking cold, as this may bring on serious complications. Persons are not likely to have this disease more than once. Isolation and disinfection should be enforced.

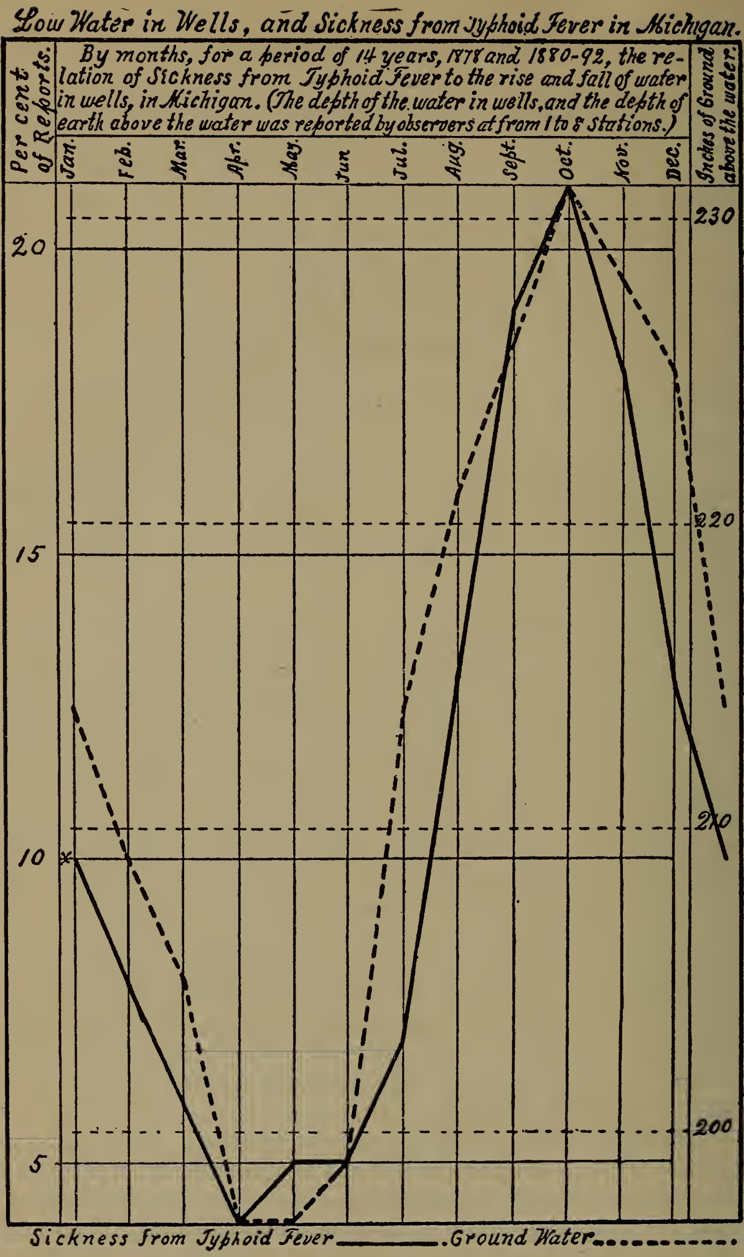


FIG. 179.

* Indicating what per cent of all reports received stated the presence of typhoid fever then under the observation of the physicians reporting.

The danger from typhoid fever is greatest in October, when the water in wells is lowest, and least in April, when the water in wells is highest.

 (Michigan State Board of Health).

Whooping Cough.—This is a communicable disease, and in the State of Michigan causes more deaths than does smallpox. This is true in most States. It is spread from person to person directly, and probably indirectly. In most cases no special treatment is needed except care to prevent the child from taking cold. If, however, the paroxysms of coughing are very severe, and weakening to the person, the physician should be called. One attack of this disease generally immunes the person from future contagion. The same rules in regard to isolation and disinfection should be observed as in other contagious diseases.

Smallpox.—This is generally looked upon as one of the worst of contagious diseases, and so it would be were it not for vaccination and our present successful methods of treating this disease. Measles and whooping cough cause many more deaths than does smallpox. (See Fig. 176.) The spread of this disease may be prevented by isolation and disinfection. By vaccination and revaccination it may not only be *restricted,* but wholly *prevented.*

Revaccination should be had at least once in five years, as one vaccination does not immune one for life. It is best also to be vaccinated whenever smallpox is prevalent, and certainly immediately after one has been exposed to the disease.

As an evidence of the value of vaccination, the following is given: In Germany, in 1871, out of a population of 50,000,000, there were 143,000 lives lost by smallpox; in 1874, after the enactment of a law requiring vaccination and revaccination, there were but 116 lives lost by smallpox, and these cases were for the most part in the towns on the frontier, where the law was not so vigorously enforced.

Only pure bovine virus should be used. This can be obtained from a physician. In being vaccinated always have it done by a skilled physician, and have him watch carefully the case.

Persons suffering from the measles, scarlet fever, erysipelas, or exposure to these diseases, or those suffering from skin diseases or eruptions, and teething children, and persons not in good health, should not be vaccinated.

Except in the cases just mentioned, every one, young and old, should be vaccinated for his own interest, and that his body may not become a breeding place for the distribution of smallpox to others.

VI. ACCIDENTS

Asphyxia. —1. *From Suffocation from Breathing Gases.* —Treat the person at once, as delay is dangerous. If, however, there is gas in the room, move at once to a room free from gas, and admit plenty of fresh air. Do not crowd around the person. Remove all close-fitting clothing that would interfere with respiration. If natural respiration has ceased, use *artificial respiration,* of which the following two methods are reliable.

(1) *The Sylvester Method.*—Place the person on his back on a level plane, slightly inclined from the feet upward, and place under his shoulders a firm cushion or a coat or quilt folded to serve as a support. Keep the head in line with trunk. Draw the tongue forward, and keep it in place by means of a handkerchief which is placed across the extended organ and carried under the chin, then crossed, and tied at the back of the neck. Kneel at the head of the patient, grasp his elbows, and draw them upward until the hands are carried above the head (Fig. 180, *a*). Keep them in this position until **one, two, three,** can be slowly counted. This produces inspiration, as it elevates the ribs, expands the chest, and thus produces a rarefaction of the air in the lungs and inrush of the air. The elbows are then gradually carried forward, downward, placed by the side, and pressed inward against the chest (Fig. 180, *b*). This lessens the capacity of the chest, causing an outflow of the air, i. e., an *expiration.* These movements should be repeated about fifteen times per minute, and kept up until natural respiration is restored, or as long as there remains any signs of life. The Sylvester Method is not successful in asphyxia of very young children, as the pectoral muscles are not sufficiently developed.

(2) *The Marshall Hall Method.*—The patient is first placed face downward, the head resting on the forearm and chest, supported by a roll or pillow. He should then be placed on his side. In each of these positions the forearm should be held so as to support the head of the patient. The mouth of the patient should be kept open, and the tongue prevented from falling back. Repeat the movements at intervals of two or three seconds. Cease the use of the artificial respira-

FIG. 180 *a*. — RESUSCITATION. INSPIRATION. (Brinckley.)

FIG. 180 *b*. RESUSCITATION. EXPIRATION. (Brinckley.)

tion as soon as natural respiration begins, unless the efforts are feeble or imperfect. Do not permit the patient to become chilled, but keep the body warm by friction and warm applications. As soon as the patient can swallow, give warm milk, coffee, or hot water. As soon as possible, put the patient in a warm bed; watch him to prevent any relapse, at the slightest indication of which, friction, and even artificial respiration, may be used. Give volatile stimulants, as ammonia, aromatic spirits of ammonia, or ether. Keep the patient quiet for some time after recovery. For adults the Sylvester Method is the better.

2. *From Drowning.*—Rule 1. *Remove all obstructions to breathing.* Instantly loosen or cut apart all neck- and waist-bands, turn the patient on his face, with head down hill; stand astride the hips, with your face toward his head, and lock your fingers together under his belly; raise the body as high as you can without lifting the forehead off the ground (Fig. 181, position 1), and give the body a smart jerk to remove mucus from the throat and water from the windpipe; hold the body suspended long enough to count slowly, **One, two, three, four, five,** repeating the jerk more gently two or three times.

Rule 2. Place the patient on the ground, face downward, and maintaining all the while your position astride the body, grasp the points of the shoulders by the clothing, or, if the body is naked, thrust your fingers into the armpits, clasping your thumbs over the points of the shoulders, and raise the chest as high as you can (Fig. 182, position 2), without lifting the head quite off the ground, and hold it long enough to count slowly, **One, two, three.** Replace him on the ground, with his forehead on his flexed arm, the neck straightened out, and the mouth and nose free. Place your elbows against your knees, and your *hands upon the side of his chest* (Fig. 183, position 3), *over the lower ribs, and press downward and inward with increasing force* long enough to count slowly, **One, two.** Then suddenly let go, grasp the shoulders as before, and raise the chest (position 2); then press the ribs, etc. (position 3). These alternate movements should be repeated ten or fifteen times a minute for an hour at least, unless breathing is restored sooner. Use the same regularity as in natural breathing.

Rule 3. After breathing has commenced, *restore the ani-*

FIG. 181.—TREATMENT OF THE DROWNED. Position 1. (Brinckley.)

FIG. 181.—TREATMENT OF THE DROWNED. Position 2. (Brinckley.)

FIG. 181.—TREATMENT OF THE DROWNED. Position 3. (Brinckley.)

mal heat. Wrap him in warm blankets, apply bottles of hot water, hot bricks, or anything to restore heat. *Warm the head nearly as fast as the body, lest convulsions come on.* Rubbing the body with warm cloths or the hand, and slapping the fleshy parts, may assist to restore warmth, and the breathing also. If the patient can *surely swallow*, give hot coffee, tea, milk, or a little hot sling. Give spirits sparingly, lest they produce depression. Place the patient in a warm bed, and give him plenty of fresh air; keep him quiet.[1]

The *Sylvester Method* may also be used for resuscitation from drowning. The mucus should first be removed from the mouth by means of a towel wrapped around the forefinger, and the water from the throat by placing the body on the face and lifting it by the hips so the water will run out. This should not take over four or five seconds.

Bleeding, or Hemorrhage. — Bleeding from an *artery* is shown by the bright *scarlet color* of the blood, and its flowing in *jets;* that from a *vein,* by the blood being of *darker color,* and *not* flowing in jets; that from the *capillaries,* by *oozing* of the blood from *several points.*

If the injured vessel is a large artery, it should have immediate attention, as there is great danger from the loss of blood. Place your finger on the spot from which the jet comes, exerting sufficient pressure to prevent the flow, and elevate the limb. As soon as possible, apply pressure by means of a *field tourniquet,* which should be placed in the course of the vessel. If it is an artery, it should be placed between the wound and the body; if a vein, beyond the wound. A field tourniquet may be made by taking a square piece of cloth or handkerchief and twisting it cornerwise, and tie a hard knot in the middle. The knot should be placed over the injured vessel a few inches from the wound, carry the ends around the limb, and tie loosely. Place stick between the tied end and the limb, and twist the bandage until the finger can be removed from the compression without a return of bleeding. Keep the patient quiet.

Get a surgeon at once. If a surgeon cannot be secured, by means of a tenaculum draw the injured blood vessel from the wound, and tie a silk or linen thread around the

---

1 Rules 1, 2, and 3 are taken from the Bulletins of the State Board of Health of Michigan, by their permission.

vessel between the tenaculum and the flesh. If you do not have a tenaculum, use a pair of small tooth pincers. Tie the thread with a "reef knot," allowing the ends to hang out of the wounds. The tourniquet may now be removed. Wash the wound, apply ice or hot water to the small bleeding points, and so bandage the parts as to draw the wound together. Let the injured part rest on an easy pillow or cushion covered with oiled silk, oiled paper, or India rubber. Leave in this condition for forty-eight hours, unless bleeding again occurs. The wound should be redressed the third day. The stiffened cloths should be first softened with tepid water. Wash the wound with warm water. The water may be antisepticized by first boiling it and allowing it to cool to the desired temperature, and adding a few drops of carbolic acid.

In case of a small vein or artery, elevate the part, and wash. Ice water or water at 46° to 49° C. may now be applied. The part should be exposed to the air. The natural contraction of the artery, with the coagulation, will control the flow, and prevent further bleeding.

Bleeding from the Lungs or Stomach. — The blood from the lungs is bright red, frothy, or "soapy," and generally small in amount. The hemorrhage usually follows coughing; the blood feels warm, and has a salty taste. Lie in bed on the back, and be quiet. While this is a very grave symptom, do not become excited; courage and rest is of vital importance. Loosen all tight clothing, keep the shoulders well raised, and the body in a reclining position. Bits of ice should be eaten freely, or alum may be held in the mouth, and swallowed very slowly until the bleeding is stopped for the time. Do not give alcoholic drinks, as these tend to dilate the arteries and to counteract the action of the styptics used.

Bleeding from the stomach is characterized by nausea, the blood thrown up is dark, not frothy, generally larger in amount than from the lungs, and generally mixed with food. The patient should be placed in a horizontal position, and on his back. It may be treated in the same way as a bleeding of the lungs.

Food should be taken in small quantities, and in a concentrated form. A good home remedy for hemorrhages is cinnamon tea; especially is it good for intestinal hemorrhage, and some other forms that cannot be mentioned here.

Bleeding from the Nose.—While this form of bleeding is most frequent, it is not, as a rule, dangerous, but rather in many cases a benefit. It is, however, sometimes quite difficult to control. Let the patient sit erect; do not lean forward, as this tends to increase the hemorrhage. Dip two cloths, of convenient size, in cold water, wring out part of the water, and wrap one around the neck and the other around the forehead and upper part of the nose. Do not blow the nose.

To a cup of water add a tablespoonful of powdered alum, and use as a snuff. If this does not stop the bleeding, make a plug for the nostril of absorbent cotton soaked in the alum water.

Fainting.— Have the patient lie flat on the back, and loosen all tight clothing. Dash cold water in the face. Hold smelling salts or ammonia to the nose. Rub the limbs, so as to force the blood toward the heart. As soon as aroused, give a dose of aromatic spirits of ammonia, thirty to sixty drops, in a third of a glass of water, or a drink of hot milk, coffee, or tea.

Fractures. — In case of broken bones, call a surgeon at once, and give him the control of the case. If, however, the case is such that immediate attention must be given, determine as near as you can the nature of the injury. Loss of power to use the limb, pain, and swelling, indicate a broken bone. Handle the parts with great care and tenderness. Make temporary splints from pieces of board, pasteboard, or bark, first padding the parts with any soft substance that is at hand, and bind the splints together by strips of cloth, pieces of handkerchiefs or suspenders. Put the limb in as comfortable a position as possible. In case it is a broken arm, support it, after the splints have been put on, by a sling.

Sunstroke. — This condition is more properly called "heatstroke." The person falls suddenly, as in fainting, from which it may be told by the head being hot. Take the patient to the shade, and bathe the head and face in cold water. Mustard plasters may be applied to the spine and stomach. Keep the patient quiet until fully recovered.

Shock.— This may result after a severe injury or from great fright. The patient becomes cold, the pulse feeble and slow; the skin clammy and bloodless; the respiration slow

and very gentle, and sometimes it may come in gasps; the eyes dull. The patient may be semi-conscious, or fully so. Restore the warmth to the body, either by friction or warm applications. Hold smelling salts or ammonia to the nostrils. As soon as the patient can swallow, give hot water, hot milk, or coffee.

VII. APPARATUS AND REAGENTS.[1]

The following estimate is made for a class of twenty.

Absorption Cotton (common).
Apparatus for warming stage (1).
Apparatus, Levers (1). (See Fig. 34*a*.)
Beakers, Griffin's, with lip, 60 c.c. (2 doz.).
Bell Glasses, low form, 4-in. (2 doz.).
Bone Forceps (1).
Bone Saw (1).
Boxes for Experiments (20).
Bulb Syringe (1).
Bunsen Burners (if there is a gas supply, (20).
Chemical Thermometer, graduated to 200° C. (3).
Circular Covers No. 2, ⅝ in. in diameter (1 oz.).
Circular Covers No. 2, ⅞ in. in diameter (1 oz.).
*Clinical Thermometer (1).
Compound Microscope, B.B.4, Bausch & Lomb (1). (See Fig. 175.) For bacteriology use, B.B.7.
Dissecting Board, 20x36-in (4).
Dissecting Microscope, Barnes (20).
Dissecting Set, in case (1): —
- 1 Scalpel; edge 45 m.m.
- 1 Scalpel; edge 25 m.m.
- 1 Scissors; medium, straight.
- 1 Forceps; heavy, straight.
- 1 Cartilage knife; all steel, edge, 45 m.m.
- 1 Tenaculum.
- 1 Triple Chain and Hook.
- 1 Blow Pipe.

*Dissecting Set (in case) (20): —
- 1 Scalpel; edge 38 m.m.
- 1 Scissors; medium, straight.
- 1 Forceps; blunt blades.
- 1 Forceps; fine, curved points.
- 2 Needle Holders and Needles.

Droppers (or bulb pipette) (20).
*Drying Oven (for air) (1).
Evaporating Dishes, 16-oz. porcelain (2).
Evaporating Dishes, 4-oz. (20).
Filter Paper, 6-in. (3 pkgs.), 8-in. (1 pkg.).
Flasks, flat bottoms, 32-oz. (4).
Flasks, flat bottoms, 16-oz. (6).
Flasks, flat bottoms, 8-oz. (20).
Funnels, glass, 6-in. (2).
Funnels, glass, 4-in. (20).
*Freezing Apparatus Attachment, for simple microtome (1).
Glass Squares, 5x5 in. (6).
Glass Squares, 3x3 in. (20).
*Graduated Cylinders, 250 c.c. (1).
Graduated Cylinders, 100 c.c. (2).
Graduated Cylinders, 25 c.c. (20).
Hessian Crucibles (small, not over 1 oz.).
Imbedding L's (1 doz.).
Imbedding Trays, porcelain, 4x4 in. and 3 in. deep (20).
*Injection Apparatus (No. 2127), (Bausch & Lomb) (1).
Injection Apparatus. cheaper form (No. 2126, B. & L.) (1).
Jars, Glass, qts. (10).
Jet Tubes, one-way (6).
Jet Tubes, two-way Y-shaped (6).

---

[1] Articles marked with a star (*) may be dispensed with, if economy is required.

Microscope Object Slides (5 gross).
*Microtome, Minot's or Bausch & Lomb's No. 2400 F.
*Microtome, student's (in place of the above; a cheaper form).
Microtome, simple.
Microtome Knife or Razor (1).
*Muscle Curve Apparatus (complete). See Fig. —.
Pith, elder or mullein.
Platinum Foil 3 cm. by 4 cm. (4 pieces).
Pulley, small (4).
*Scales, Apfel's Improved Triple Beam No. 1.
*Skeleton, human (articulated).
*Skull, human (disarticulated).
Set Reagent Bottles.
Spatulas, steel blades, 4-in. (2).
Sponges, coarse, large (6).
Spirit Lamps (20).
Test-Tube Racks (20).
Test Tubes, 8-in. (½ gross).
Test Tubes, 6-in. (1 gross).
Test Tubes, 4-in. (1 gross).
Tubing, soft rubber, 3–16 in. diameter (20 ft.).
Tubing, hard rubber, 3–16 in. diameter (20 ft.).
Tubing, glass, 3-16-in. (2 lbs.).
Turn Table (1).
U-tubes (½ doz.).
*Watch Glasses, Syracuse, solid.
*Water Bath, Naples (simple form).
*Weight, iron (½ to 32 oz.).

REAGENTS.

Acid —
Acetic ....3 lb.
Carbolic (phenol)........8 oz.
Chromic ....1 lb.
Hydrochloric (muriatic)...6 lb.
Nitric (aqua fortis)......6 lb.
Oxalic ....4 oz.
Picric ....4 oz.
Sulphuric (oil of vitriol)..8 lb.
Tannic ....2 oz.
Alcohol —
Methyl (wood spirits), for lamps if needed..........2 gal.
Ethyl (spirits of wine or common alcohol).........3 gal.
Ammonium Hydroxide (aqua ammonia), 28 per cent...1 gal.
Ammonia Carmine..........8 oz.
Ammonia Chloride..........4 oz.
Ammonium Chloride........4 oz.
Ammonium Molybdate......¼ oz.
Ammonium Potassium Dichromate ....2 oz.
Antimony (metallic powdered) ....1 oz.
Agar-Agar ....1 lb.
Arrowroot ....2 oz.
Baking Powder............½ lb.
Balsam, Canada (in benzole) ½ pt.
Barium Chloride............4 oz.
Beef Extract (Lieb's), 4 oz. (can)
Benzene ....1 lb.
*Bismarck Brown..........⅛ pt.
Bismuth Hydroxide.........2 oz.
Brunswick Black...........¼ pt.
*Borax Carmine (Grenacher).
Canada Balsam. (See *Balsam.*)
Carbolic Acid. (See *Acid.*)
Carmine ....2 oz.
Carron Oil (for accidents from burns or acids).....½ pt.
Chlorine Water (make as needed ....1 pt.
Chloroform ....1 lb.
Chromic Acid. (See *Acid.*)
Clove oil (see *Oil*).........⅛ pt.
Collodion ....4 oz.
Copper (metallic wire or turnings) ....4 oz.
Copper Sulphate (Blue Vitriol) ....4 oz.
Cotton Wool................2 lb.
Cream of Tartar (see Potassium Hydrogen Tartrate).4 oz.
Dammar (in benzole).......1 pt.
Eosene ....⅛ pt.
Ether (sulphuric ether)..1 lb. can
Fehling's Solution (see *Glossary*) ....¼ pt.
Ferric Chloride.............2 oz.
Ferrocyanide of Potassium (see *Potassium*).
Ferricyanide of Potassium (see *Potassium*).
Formalin ....1 gal.
Frey's Carmine (see *Carmine*).
Gelatin ....1 lb.
Gibbe's Double Stain for Bacillus ....⅛ pt.
Glycerine ....4 oz.
Gold Chloride (5 per cent solution) ....⅛ pt.
Granulated Zinc. (See *Zinc.*)
Gum Camphor...............1 oz.
Hæmatoxylin —
Grenacher's ....½ pt.

*Double Stain, Weigert's (Solution I and II) ...... ½ pt.
Hydrochloric Acid. (See *Acid.*)
Hydrogen Disodium Phosphate .... 2 oz.
Hydrogen Peroxide (dioxide) (U. S. P. sol.) .... 1 lb.
Hydrogen Sulphide (make as needed) .... 1 pt.
Iodide of Potassium (see *Potassium*)....... .. .. ..
Iodine .... 1 oz.
Iodized Serum .... ½ pt.
Iron Sulphide.............. 1 lb.
Lead Acetate (sugar of lead) 8 oz.
Lime Water (make as needed) .... ½ gal.
Litmus (in cubes or powdered) .... ½ oz.
Litmus Paper —
Red .... 10 sheets
Blue .... 10 sheets
*Loeffler's Methylene Blue, for bacillus .... ⅛ pt.
Magnesium Sulphate........ 4 oz.
Manganese Dioxide (black oxide) .... 1 lb.
Mercuric Chloride.......... 2 oz.
Mercuric Nitrate........... 2 oz.
Mercuric Oxide (red oxide), (red precipitate)......... 4 oz.
Mercury (metallic)......... 1 lb.
Millon's Reagent......... ¼ pint
Nitric Acid. (See *Acid.*)
Nitrate of Silver. (See *Silver.*)
Normal Salt Solution. (See *Solution.*)
Oil of Cloves.............. ⅛ pt.
Oil, olive.................. ½ pt.
Oil of Turpentine.......... ⅛ pt.
Oxalic Acid. (See *Acid.*)
Pancreatin .... ½ oz.
Paraffin, 45° C............ 3 lb.
Paraffin, 53° C............ 1 lb.
Pepsin .... ½ oz.
Persulphate of Iron......... 2 oz.
Picric Acid. (See *Acid.*)
*Picrocarmine (Weigert) ... ½ pt.
Platinum Chloride ($PtCl_4$), 2-per-cent solution...... ⅛ pt.
Potassium Acid Tartrate.... 4 oz.
Potassium Chlorate .... 8 oz.
Potassium Chloride .... 2 oz.
Potassium Dichromate (bichromate) .... 4 oz.
Potassium Hydroxide (caustic potash) (sticks).......... 1 lb.
Potassium Iodide .... 2 oz.
Potassium Ferricyanide .... 2 oz.
Potassium Ferrocyanide .... 4 oz.
Potassium Nitrate .... 2 oz.
Potassium Permanganate ... 4 oz.
Potassium Pyroantimonate.. 2 oz.
Silver Chloride .... ⅛ oz.
Silver Nitrate (lunar caustic) .... ⅛ oz.
Sodium Bicarbonate .... 4 oz.
Sodium Carbonate .... 4 oz.
Sodium Chloride .... 4 oz.
Sodium Hydroxide (caustic soda) (sticks) .... 1 lb.
Sodium Sulphate (Glauber's salts) .... 4 oz.
Sodium Sulphide .... 2 oz.
Solution of Acetic Acid, 3 per cent .... 1 qt.
Solution of Alcohol, 40 per cent .... 1 gal.
Solution of Alcohol, 60 per cent .... 1 gal.
Solution of Alcohol, 80 per cent .... 1 gal.
Solution of Ammonia, 10 per cent .... 1 gal.
Solution of Chromic Acid, 2 per cent .... 1 pt.
Solution of Gold Chloride (see *Gold Chloride*), 5 per cent.
Solution, Fehling's .... ½ pt.
Solution, Mercuric Nitrate (acid) .... ½ pt.
Solution, Mercuric (neutral) .... ½ pt.
Solution, Normal (salt), 6 per cent of salt.......... 1 gal.
Synthol .... 1 gal.
Tannic Acid. (See *Acid.*)
Tincture of Guaiacum (guaiac) .... ⅛ pt.
Tincture of Iodine......... ⅛ pt.
Turpentine, Oil of. (See *Oil.*)
Turpentine, Spirits of...... 1 gal.
Zinc, Granulated .... 1 lb.
Zinc, White Cement........ ⅛ pt.

VIII. BOOKS FOR REFERENCE.

Anatomies. — Gray, Hertzmann, Quain, Morris, Henle, Holden.

Physiologies. — *American Text-Book of Physiology*, Howell; *Text-Book of Physiology*, Foster; *Text-Book of Physiology*, Landois and Stirling; *Animal Physiology*, Mills; *Comparative Physiology*, Mills; *Hand-Book of Physiology*, Kirke; *Human Physiology*, Schenck and Gümber.

For Laboratory Guides. — *Practical Physiology*, Foster and Langley; *Anatomical Technology*, Wilder and Gage; *Dissection of the Dog*, Howell; *A Laboratory Guide in Physiology*, Hall; *Physiology Practicums*, Wilder; Zoötomy, Parker; *The Microscope and Microscopical Methods*, Gage; *The Microtomist's Vade-Mecum*, Lee; *The Micrographic Dictionary*, Griffith Henfrey; *Illustrated Dictionary of Medicine*, Gould; *Text-Book of Normal Histology*, Persol; *Elements of Histology*, Kline; *Essentials of Histology*, Schaeffer; *Aquatic Microscopy*, Stoke.

Periodicals. — *Journal of Applied Microscopy*, Bausch and Lomb Optical Co., Rochester; *American Journal of Microscopy and Popular Science*, New York; *Anatomischer Anzeiger*, Jena; *International Journal of Microscopy and Popular Science*, London; *Journal of Anatomy and Physiology*, London and Cambridge; *Journal of the Royal Microscopical Society*, London.

Hygiene. — *Hygiene of the Sick-Room*, Canfield; *Hygiene and Public Health*, Parkes; *Treatise on Hygiene*, Stevenson and Murphy; *Ventilation and Heating*, Billings; *Practical Dietetics*, Thompson.

AUG 11 1902

AUG. 14 1902

LIBRARY OF CONGRESS
0 005 524 532 0